

Transactions of the
**Royal Society
of Canada**

Mémoires de la
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1993 / FIFTH SERIES / VOLUME III
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Opening Statement[†]

ON ISSUES of global change and environmental concern, the Royal Society has already taken a firm leadership position in Canada, and we applaud that energy and direction and sustained effort to promote sustainable development. But having raised the level of debate, having raised awareness, one must plan for action, and that means addressing specific issues. Water must be a top priority.

On water, the life blood of the environment, we at the Science Council share the specific concerns of the Royal Society and many other groups who have been arguing eloquently, but often with both passion and frustration for at least two decades, for a national water policy with teeth and a collective stewardship of our rather priceless water preserves. Now we are at last beginning to see some action. There is a Federal Water Policy which acknowledges the need for leadership. What action next?

On 31 May we released *Water 2020, De l'eau pour demain: Sustainable use for water in the 21st century*, discussed below by Dr. Robert Fournier, chairman of the Science Council committee that wrote the report. In June we released *Winning in a World Economy*, focusing on the importance of university / industry and research innovation cooperation to sustain intellectual excellence and international market competitiveness for our very economic survival in Canada.

We are faced with a new economic paradigm, that of a global economy where the variables are all linked—the growth in tradeable goods and services has supplanted that in resources. Tradeable goods and value-added resources have become the primary exchanges, and knowledge and information the most valuable currency. Indeed, knowledge is the hardest currency of all.

*Chairman, Science Council of Canada.

†Presented at the symposium, "Future Changes and Challenges to Canadian Water Resources," University of Windsor, 6 June, 1988.

However, international global competitiveness takes place in a world in which the environment must have a chance to maintain its quality, its freshness, and its integrity—in which actions for preservation outweigh actions leading to more pollution. So the two themes of our reports come together rather naturally in the context of sustainable development, as covered by the Brundtland Commission in *Our Common Future*. For the future of Canada, the future of the globe, we appeal for a change in the way of thinking about traditional problems such as population growth and demand and supply, which underlie economic and environmental crises. They are linked inextricably for the future, and old solutions may not work—the response of the system is no longer simple and clear. Global activity is a nonlinear system whose many variables are complex and interdependent.

It is ironic that Marshall McLuhan, a Canadian, gave the world a phrase in the 1960s which rang resonantly, "The Global Village." In Canada we focused on *village*, not GLOBAL! It is now time to refocus our views to see all our activities in the global context. We must leave our villages, our regions, our countries, our narrow parochial perspectives, and look beyond, to other countries, other mountains, other fields and shores and seas. We have but one planet; we share a collective stewardship of our global commons. We cannot give up the imperative toward international industrial market challenges, because without a healthy injection of created wealth there will be no fiscal support for enlightened research toward solutions for these problems. Nor will we be able to meet the social expectations that grew from our earlier prosperity. But we can and we are challenging each other to address simultaneously the environmental questions and the technological options.

From water quality and pollution to new technologies, water resources, and water management, water is everyone's business now. So I would like to conclude my remarks by posing some questions which should be part of our continuing discussion about action. These questions involve finance, research, jurisdictional issues, and some major current events, which serve as examples for the need for an integrated action plan. Let me begin with current affairs.

What are the implications on the large-scale diversion of freshwater to the United States, such as the proposed Grand Canal scheme? At this very moment, U.S. authorities are under political pressure to divert water from Lake Michigan via Chicago to flow into the dangerously low Illinois and Mississippi rivers in the drought-stricken Mississippi Valley.

The Science Council's fundamental position is that the *status quo* on water resource management is neither appropriate nor responsive to such major issues in an *integrated* way. Diversions can only be considered in the total, larger environmental scheme, and while some diversions may be a good strategy, some may not. Each requires careful analysis. For example, models predict that diversion to the southern USSR of as little as five per cent of the fresh water currently flowing into the arctic could produce long term and catastrophic warming trends.

How could severe water shortages, such as those currently occurring in Western Canada, be avoided? Of course, to a certain degree, the climate always fluctuates naturally. It is the man-made extremes which must be controlled. One response takes us in the direction of water efficiency and conservation policies, another perhaps to water diversions, a third to new types of water recovery and water management. A perfect example of the need for long-term planning is given by the twin extremes of flood and drought, both currently being experienced in Alberta and Saskatchewan. The Science Council will publish a discussion paper on conservation technology arising from the background work to *Water 2020*.

Any plan requires a clear understanding of jurisdictional responsibilities. All the recommendations in the Science Council report are directed at the federal government, primarily Environment Canada. However, do not the provinces and municipalities have major responsibilities for water management and encouraging better water quality? Of course, all levels of government share a major jurisdictional responsibility for water. But when over twenty departments of governments are involved in making decisions or regulations to solve one question, an overall strategy is needed if anything is to be accomplished. Alas, too many unhappy examples already abound. Environment Canada has a leadership role to play and could coordinate the other players through consultations. It is crucial that the jurisdictional issues be resolved, and that requires a mobilisation of political and public will for consensus and national action.

Jurisdictional issues are not independent of financial questions. For example, some might ask why the report did not have more to say about management of demand and water pricing and municipal responsibilities. Clearly the low prices and variations from country to country in water pricing, which are mentioned in the report, do not reflect the real costs. These points need more serious debate. To regulate the use of water through pricing is one option which could be a source for new technology risk-sharing funds. However, our emphasis was on a *new paradigm*, on a new framework for long-term thinking about water as the life blood of this planet. Water cannot be treated merely as a commodity. The Science Council is arguing that a longer perspective must be taken, and a co-ordinated framework be established for the S&T policy issues involved within this new paradigm. To those who are concerned that water would be treated as a mere commodity under the Canada-United States Free Trade Agreement, we point out that since 1909 this has been an ongoing issue of concern to Canada. Current FTA discussions leave an ambiguity in the air. Future national and international water policies must be related to these new long-term perspectives or the public unease with respect to water trade will not abate.

Ultimately, it is the quality of water that is of paramount concern to the public. It would appear that about \$56 million annual funding is presently allocated towards water-related research addressing water quality standards

and hydrological or aquatic ecosystems problems. While that amount sounds substantial, are we getting the best value for that investment from an integrated, coordinated perspective? Should more research be encouraged and sponsored, and if so by whom? What are the important and yet unanswered hydrological assumptions that need to be tested as a prelude to informed decisions or actions? What issues concerning the effect or transportation of pollutants need research so that we can develop more reliable theories and then models of macroscopic or microscopic behaviour, from climate change to ion transport properties across membranes?

Finally, are there any estimates of the economic returns to Canada of commercializing clean water technologies? On this last point, it is clear that, world-wide, the answer is that such returns are several billion dollars a year; in Canada potentially a few \$100 million are involved. Of more importance for policy initiatives is that there is a five- to ten-fold increase in industrial economic opportunity over the existing industrial efforts. The private sector could be challenged to meet these opportunities if a longer-term policy climate of incentives for technology transfer and commercialization was established. From aquatic ecosystems to coastal runoff, the Science Council report lays out a number of scientific and technological issues, each of which could be associated with an opportunity for leadership in research, in developing technologies where appropriate, and in sharing those technologies with developing countries.

In conclusion, the Science Council feels that the public perspectives on water issues must be broadened considerably. We ask that jurisdictional credibility, professional water expertise, and public involvement be integrated into a constructive, co-ordinated and progressive long-term plan.

Water is where everything begins. Our long-term economic well-being will be at risk if immediate action is not taken to improve water quality, resources, and management practices for renewable supplies. It is not very difficult to imagine water as the geopolitical resource of the 1990s, as oil was in the 1970s. To seek quality, quantity, and regional equity, demands leadership now, in Canada and in all other countries. Otherwise it appears inevitable that freshwater reserves will drop, water will be priced like a luxury, farming and irrigation will have to be abandoned in some regions, and the significant cost of dealing with toxic waste resulting from existing industrial practices will look small compared to the societal costs of losing environmental integrity, of losing fresh and freely flowing water.

Water 2020—the Science Council of Canada hopes that by that year it will be possible to look back at the late 1980s as a time when the right decisions were made on water, the lifeblood of our planet, of our nations, of our villages. With 2020 hindsight, the next generations may indeed wonder why it took us so long to act. This symposium should be part of the historical record of effective action.

Water 2020: Sustainable Use for Water in the 21st Century[†]

WATER 2020 is the final report of a water study launched by the Science Council of Canada in 1986. The report argues the need for a radically new attitude toward our environment, and toward water in particular. To meet emerging needs the report calls for a national commitment to a common purpose, and a number of important changes to realign our resources for science and technology to achieve sustainable development—to assure a healthy environment and economic prosperity.

GETTING STARTED

How did it all come about? What made us feel such a study was warranted—especially one following so close on the heels of the *Inquiry on Federal Water Policy* (the Pearce Report) published in 1985?

First, some background. The Science Council has been interested in water policy almost since the time of its inception. For example, in 1968 we published Report 3, *A Major Program of Water Resources Research in Canada*, and Special Study 5, *Water Resources Research in Canada*. These publications helped set the agenda for water research until the mid-1980s. Then in 1985 we co-operated with the Inquiry on Federal Water Policy to co-sponsor a paper entitled *Water Resources Research in Canada: Issues and Opportunities*. This paper was later incorporated into the Pearce Report.

The Pearce Report represented a major effort. There had been thirty-three days of public hearings across the country and a budget beyond the Council's

* Associate Vice-President (Research), Dalhousie University, and Member of the Science Council of Canada.

[†] Presented at the symposium, "Future Changes and Challenges to Canadian Water Resources," University of Windsor, 6 June, 1988.

wildest dreams. But what we felt it lacked was a fresh perspective on water, one that treated water as more than a commodity and that considered the interdependence of water and other sectoral issues. In addition, water resources research was only one small part of the Pearce Report, and the linkages between science policy issues and the policies affecting the management of water use were not explicit. Subsequently, the Council received enthusiastic support for its proposed new study from Environment Canada and other federal departments, as well as from provincial departments and other agencies across the country. With this support, the Science Council established a water resources committee to extend the work of the federal inquiry and promote a new depth of understanding about how water should be used.

The Committee, which included four members of the Science Council and four water experts, established an eighteen-month schedule. An initial workshop was held with participants from all parts of Canada to help identify emerging research needs. The following year, participants at six regional workshops reviewed the key issues as identified by the Committee and debated policies that might aid in their resolution. All this work was backed by several specially commissioned research papers on topics ranging from water conservation and demand management to the long-range transfer of pollutants. At the same time, project staff consulted water scientists in government, industry and university, and water-use managers, policy makers, and others across the country to get their views and opinions on the future of water science.

DO WE HAVE A PROBLEM?

Canadians form less than 1 per cent of the world's population and occupy 7 per cent of the world's total land surface. They can lay claim to 20 per cent of the total fresh water in the world and 9 per cent of the renewable fresh water. Perhaps, then, there should be little wonder at the reluctance of many Canadians to face the fact that, despite its apparent abundance, our supply of usable water could run out. At the press conference in Ottawa to launch our final report the question repeatedly posed, in various ways, was whether the report was not "alarmist." This expression of doubt in the face of the facts (and in the midst of major drought affecting much of North America) is surely itself part of the problem of rallying our resources to meet long-term needs.

The committee began its work aware of the extensive and accumulating evidence of the need for urgent action to maintain the health of our water systems:

- Shortages of fresh water and pollution threaten the health of many Canadians, and the quality of drinking water is a problem in several parts of the country.
- Demand for water in the southern Prairies and the interior of British Columbia already approaches the limits of supply.

- In 1987, even in Newfoundland, water was scarce. Residents had to boil water for drinking, others had to travel long distances to obtain water, and economic activity was severely affected.
- More than 360 chemical compounds have been identified in the Great Lakes.
- At a local level, pollution is widespread, destroying the biota of countless lakes and streams.
- As many as one hundred thousand lakes have already been damaged by acid rain, while some aquatic systems in north-eastern North America have lost up to 20 per cent of their species because of acidification.

In the longer term, no one knows precisely what pressures on water resources future climatic change might bring. By 2020 the global population will have doubled to around 10 billion, of which 90 per cent will be in the Third World. Even comprehensive and well-integrated water-management schemes will be inadequate to sustain the increase in population in Europe and South and East Asia. Africa will also face acute water problems. Canada could come under financial and moral pressure to export water to the United States. Indeed, should current rates of global deforestation and erosion continue, with the inevitable disruption of drainage systems and water supply, the 1980s could come to be viewed by Canadians as a golden age.

THE GLOBAL CONTEXT

Protecting the Canadian environment, and with it, Canadian water, is primarily a domestic responsibility. But the committee rapidly concluded (and even a selective review of current domestic water issues bears this out) that we are moving away from a period of acute, localized, and relatively simple problems to one of chronic, global, and extremely complex problems.

The potential impact of a diversion of freshwater runoff into arctic waters is a case in point: freshwater runoff into arctic water helps maintain low salinity in the upper layer. This acts like a lid preventing warmer, deep water from reaching the surface, which would increase the flow of heat and moisture into the atmosphere, thereby altering global weather patterns. Depriving arctic waters of as little as five per cent of their supply would warm the Arctic and trigger climatic change over a wide area, possibly on a global scale. In this case, as in others, the demand for water and the impact of economic and social activities at any one point in its flow are transferred throughout the total system.

THE ROLE OF SCIENCE IN SUSTAINABLE DEVELOPMENT

The Committee concluded that just as Canadian water problems can only be tackled in a global context, water problems must also be viewed within a broad environmental context. All the major environmental trends that threaten the

planet impinge directly or indirectly on the availability of fresh water or the need for it. Degradation of water, soil, atmosphere, and forests form interlinking processes of cause and effect that span the continents. The impact in terms of hunger, overpopulation, erosion, climatic change, and species diversity must concern water scientists. Two of the most pressing problems we face—large-scale river diversions and groundwater contamination—reinforce this point by showing the interconnectedness of environmental, economic, social, and other factors.

- The manipulation of the water system associated with James Bay has sufficiently altered the flow of fresh water into the Gulf of St. Lawrence to harm the fisheries along the Labrador shelf; the same manipulation has increased the mercury content in fish in James Bay to the highest level in the world. Similarly, in Egypt, the Aswan Dam has resulted in serious erosion that is destroying a once profitable fishery and has increased the incidence of schistosomiasis. Longer term impacts including climatic change and re-distribution of rainfall remain unresolved.
- There are more than two million water wells in Canada. Twenty-six per cent of Canadians (6.2 million people) rely on groundwater for domestic purposes. As well, almost all farm livestock depends upon it. Total groundwater in Canada amounts to thirty-seven times that in our lakes and rivers. Yet groundwater and the extent of its pollution from domestic, industrial, and other sources remain poorly understood. In New Brunswick alone, since 1979, five hundred wells have been contaminated by leaking petroleum tanks. And it is often impossible to restore polluted groundwater to potable quality.

It was obvious to us that policies in response to these issues need to be long-term, comprehensive, and inter-related, and that they should be based on science. But how we use science to respond to these water issues is also important. Unless we want to continue to use science only as a remedy for environmental mismanagement and ignore its potential to anticipate and prevent problems, we must decide what kind of environment and economy we want and apply science to achieve it. To continue on our present path of over-exploitation is indefensible. The Committee was resolved that Canadians must move towards a policy of sustainable use for water or risk economic and environmental collapse. To guide water research, therefore, we developed the following principle: "We must manage water use to meet present needs in an equitable manner and without compromising the ability of future generations to meet their own needs."

This principle is consistent with the overall goal set in the *Federal Water Policy* and is firmly embodied in the final report of the World Commission on Environment and Development (the Brundtland Report). Indeed this Report, released in 1987 when our own study was already under way, directly links

environmental management to technological development and economic growth and indeed argues for a new era of economic growth in which technology will be used to solve environmental problems and to promote sustainable development, themes the Water Resources Committee and the Science Council strongly endorse. But such a goal requires new policies which will integrate the environment and the economy and direct technology to this end.

THE INSTITUTIONAL BARRIERS TO APPROPRIATE WATER RESEARCH

Drawing on its collective experience the Committee adopted the hypothesis that existing arrangements for water science are inadequate to address future issues. The process of investigation followed by the Committee rapidly confirmed this hypothesis and identified a series of specific problems:

- Existing institutions involved in water research do not co-operate with each other: as many as twenty federal departments or agencies are involved in water research; in addition many different provincial departments, universities and private companies have some involvement in water-related activities.
- They focus on short-term, managed research, i.e., research geared to day-to-day management of water issues rather than long-term strategic needs.
- They promote research with a narrow disciplinary focus.
- They rely heavily on federal funding, leaving them particularly vulnerable in periods of financial constraint.

WHAT TO DO?

To remove the institutional constraints on water research the Committee concluded:

- Environment Canada should publish its strategic interest and long-term research plans in water science and recognize the role of science, and of water science in particular, in the department.
- Environment Canada should take joint action with other federal departments involved in water research and seek funding of \$40 million a year to establish associate laboratories.
- Environment Canada and other federal departments should co-operate to set up a new water science training program to ensure an adequate supply of young scientists with a suitable interdisciplinary background.
- Federal departments should recognize the right and responsibility of their scientists to participate in public interest groups and to ensure that those groups are represented on the advisory boards of federal water research centres.

- Government scientists should have more opportunity to engage in international consulting in water-use management since this provides a valuable source of experience and training for Canadians as well as a shop window for Canadian water science.
- The Department of Industry, Science and Technology should launch a strategy to develop better technologies for reducing the demand for water and for preventing or relieving pollution.

WATER AS A LIFE FORCE

Important as these specific recommendations are, in themselves they are no panacea, nor can they be viewed as necessarily adequate to meet all long-term needs. Yet they do outline the direction in which the Committee believes we must move if we are to meet long-term needs. There remains a continuing challenge to develop policy objectives that can encompass uncertainty, especially for those water issues for which the consequences of policy inaction are too great. Above all, and this was a recurrent theme in all our deliberations, there is a need for a new philosophy, a new way of thinking about water that will allow us to understand fully its importance beyond any narrow "commodity" role.

Ivan Illich in his book *H₂O and the Waters of Forgetfulness* introduced the concept of water as a "life-force." The Committee enthusiastically embraced this concept—albeit with some reservations about the specific terminology and its mystical connotations. Yet we can no longer ignore, as we have so often done in the past, that water is indeed the life-blood of the environment and that without water no living thing, plant or animal, can survive. Water returns to us both the benefits and disasters of our civilization. Technology can and does affect our water in more than one way. The evidence presented to the Committee suggests that human life itself is threatened unless we adopt a value system that places environmental integrity above all but the most basic human needs. The natural environment must be recognized as providing the context for political and economic decision-making rather than as merely one consideration among many. Canadians are not owners of waters, we hold only limited stewardship rights.

OASIS IN SPACE

A recent review of Euan Nibet's *Oasis in Space* (New York: Preston Cloud, 1988) in *Science* (240, 10972, 20 May, 1988) illustrates the very message the Water Resources Committee wants to leave:

Hippos do not just sleep on sandbanks. Hippos have incongruously tiny tails, which do more than keep off flies. When a hippo defecates, which it does with great éclat, the co-evolutionary tail whirs around like a fan. The dung hits it, is spread far and wide, and

nurtures the riverbank habitat—when we remove the hippo we also leave the riverbank, the river, and the world much the worse.

Our planet is in crisis. Misuse of our water resources compromises the basic integrity of our total environmental system and, with it, our economic well-being. That is the bottom line of the Council's report.



Acid Rain: The Divergence of Research and Politics†

IN 1970 I climbed to the top of a hill in the La Cloche Mountains of Ontario and looked down on Lumsden Lake. There was a solitary fisherman in a solitary boat on this solitary lake in the mountains. I thought: what could be more idyllic? But there was one thing wrong with this idyll: the fisherman wasn't fishing, he was drowning worms. All of the sport fish in this lake had become extinct in recent years: yellow perch and burbot in 1960; lake trout and slimy sculpin in 1967; and white sucker, lake herring, and trout-perch in 1969, leaving lake chub as the only species present. Five lakes upstream of Lumsden Lake were void of fish of all kinds, but until recently some of these lakes had supported sport fisheries. The outlet stream of Lumsden Lake flows over an impassable falls and thus fish immigration has been blocked since Lumsden Lake was isolated from the Algonquin Great Lakes eight to ten thousand years ago. Two hypotheses may be proposed to explain this disappearance of fishes: (1) fish populations become extinct spontaneously, and historically they were replaced by indigenous peoples; (2) a recent change in water quality has made these lakes inhospitable to fishes. The first hypothesis is not testable by the scientific method but the second is. The pH of Lumsden Lake declined from 6.8 in 1961 to 4.4 by 1971. Based on the very low pH of rain and snow samples collected in the 1960s and 1970s, the hypothesis was advanced that this lake acidification was induced by acid deposition, and that the fishes of this lake could not tolerate the high concentration of hydrogen ion.

The term "acid rain" is not new, having been coined by Angus Smith in 1852. The disappearance of fish populations from lakes also is not new. In 1915 Dr. Høyer from Arendahl, in south-eastern Norway, identified the disappearance

* Department of Zoology, University of Toronto.

† Presented at the symposium, "Future Changes and Challenges to Canadian Water Resources," University of Windsor, 6 June, 1988.

of brown trout from remote mountain lakes. The linking of acid rain and the loss of fishes was not made until the 1950s when Dannevig reported the sensitivity of surface waters to acid deposition and the associated reduction in the densities of fish populations.

In North America the broad recognition of an acid precipitation problem was delayed by other environmental concerns of the 1960s and early 1970s: mercury contamination and eutrophication of waters such as Lake Erie. There was also the credibility problem. The first attempt at publication of the acidification of the La Cloche Mountain lakes by Beamish and Harvey elicited the editorial response: "If any thing on the scale that you describe was happening, someone else would have seen it first." Large-scale environmental problems such as deforestation, global warming, and reduction in the ozone layer, gained acceptance only in the late 1980s.

The evidence that acidification of surface waters is occurring comes in many forms:

- 1 the loss of alkalinity and decline in pH over time
- 2 the changing composition of waters from biocarbonate to sulphate dominated
- 3 the increasing concentrations of metals in waters, especially aluminum and manganese
- 4 the loss or absence of acid-sensitive species
- 5 the similarity of responses between organisms in natural but acidifying environments and the responses of such organisms to experimentally induced acid stress
- 6 the geographical concurrence between areas of acid deposition and acidification effects
- 7 the observable effects of precipitation events, acid rains, and snow melts on water chemistry and aquatic organisms
- 8 the changing pH of lake sediments, based on pH tolerance of the organisms deposited during recent decades.

Such direct evidence is supported also by the predictive capability of acidification models.

These categories of evidence became the basis of the acidification concern in Norway, Sweden, and then Canada, in the 1970s and 1980s. The process is to define the geographic scope of the problem, define the changes that have occurred, and define the rates of change. To these more recently have been added attempts to define the "critical load" or threshold of environmental perturbation by acid deposition, and to predict the rate of recovery if acid loading is reduced.

Such an approach to defining the problem has not gained universal acceptance. In the *Final Report, United States-Canada, Memorandum of Intent on Transboundary Air Pollution* (January 1983) a disclaimer is found:

"The U.S. members of the Work Group believe the statements in this section cannot be supported by the facts. The combined analysis of lake survey data, terrestrial mapping data and deposition data is an interesting methodology. Pending validation, the U.S. members have too many concerns about the influence of uncontrolled variables to consider its use more than speculative . . ."

Similarly, a recent review of the effect of acid deposition on the disappearance of fishes from the Adirondack lakes concluded that no causal link could be made between acid rain and fish extinctions. Such reports are contrary to the methodology of science—erect and test hypotheses, retaining that one which best fits the observations. No alternative hypothesis has been advanced for the acidification of lakes and streams and the loss of species from the Adirondack lakes.

In Norway one alternative explanation was advanced for the acidification of lakes, streams and rivers. Changes in land use, that is, agricultural practices, were responsible for the acidification of soils and hence of the water passing through such soils. Exhaustive analysis of the massive data base on the lakes of southern Norway revealed that acidification of surface waters occurred both where land use had changed and where it had not. These results came as no surprise, in that so many of the acidified lakes of southern Norway were in sparsely forested mountain catchments that had never been agricultural.

How much environmental damage is enough to make the case against acid rain? Considering the reluctance of governments in Europe and North America to legislate control measures, a high "body count" is a prerequisite. At what point does this strategy become self-defeating? During the period 1972–80, the Norwegian SNSF project assessed the loss of brown trout populations: 54 per cent of such populations had been lost from some 2,600 lakes in southern Norway. The presentation of this evidence at Sandefjord in 1980 generated this response from the major acid polluter: If you have already lost more than half the lakes, then it is not worth the cost to us to reduce emissions to save what is left. So the "body count" criterion is a Catch-22. To make a case against acid rain you need to lose the resource; having lost the resource there is no need to reduce emissions.

Perhaps the cardinal feature of the acid rain problem has been the inability of governments to agree on a definition of how much damage is enough. For example, must the damage approach or equal the cost of emissions reduction? Frequently, total costs of reducing emissions are matched against only one aspect of environmental damage. Thus the former Director of the U.S. Office of Management and Budget related damage to the Adirondack lakes to the cost of a reduction in all U.S. emissions: "Does it make sense to spend billions of dollars controlling emissions from sources in Ohio and elsewhere if you're talking about very marginal volume of dollar value, either in recreational terms or commercial terms?"

What constitutes "proof" of a relation between acid deposition and acidification of surface waters? It has been proposed recently that the death of

an individual fish in a specific lake must be shown to be due to a specific smokestack. This criterion is in sharp contrast to the science-based one required before implementation of a reduction in phosphate loading to the Great Lakes. It was not required that the scientists demonstrate which algal cells in Lake Michigan were growing more quickly in response to the phosphate from Mrs. Murphy's dishwasher in Milwaukee. The scientific evidence deemed sufficient at that time was that the eutrophication of the great Lakes would continue at current levels of phosphate loading, that is, on simple mass balance. In the case of acid rain, it is impossible to attribute the acidification of a single water body in Quebec or Ontario to any one of the coal-fired generating plants, for example, in the Ohio River valley: the effluents mix and fall as acid rain or snow in varying amounts in each precipitation event, regionally, seasonally, and annually. Yes, the plumes of individual smokestacks can be, and have been, tracked through the addition of unique halogenated hydrocarbons to stack gases. But research programs designed to tie specific organism deaths to specific stack emissions do not now exist and may not be practical.

What can science say about acid rain? There are six links between the burning of fuels or smelting of metals and the loss of the biota. Each of these linkages can be stated as a testable hypothesis:

- 1 Emissions of SO_2 and NO_x are subject to long-range transport in the atmosphere.
- 2 Acid deposition is proportional to such acid-forming emissions.
- 3 Acid rain and snow reduces alkalinity and pH in surface waters directly and by cation denudation of the watershed.
- 4 The increased acid in rain and snow leaches metals from soils and into aquatic systems.
- 5 Metals such as monomeric aluminum are toxic to some organisms.
- 6 The failure of fish populations in acidifying water to recruit new age classes into the population is due to low pH and high aluminum concentrations.

All of these hypotheses are readily testable and the scientific literature abounds with such information. Currently about six hundred papers are being published annually on acid rain—its origins, atmospheric chemistry, deposition, and effects. Perhaps the most effective test for some of these hypotheses is the restoration of lake alkalinity by direct application of base, in the form of powdered limestone ("liming"). The effects are elevation of pH, precipitation of metals, survival of young fishes and hence recruitment of new age classes into the populations. In Sweden, more than twenty-five hundred lakes have been so neutralized and thus there is an abundance of evidence that the low pH was the cause of the failed recruitment in fish populations. In that the limestone so applied is consumed by the continuing acid deposition, a Gran titration on an ecosystem scale, there is a good measure of the rate of loss of base to neutralize the incoming acid.

The acid neutralizing capacity of the natural environment clearly varies with type and depth of soil, proximity and type of bedrock, plant cover, and duration of exposure to acid deposition. In the first stage, the incoming acid reacts with any available carbonate or bicarbonate. When this is exhausted the acid reacts with silicate minerals, with hydrogen ion displacing Ca, Mg, Al, Mn, Fe from the mineral lattice. This is a slower process and unreacted hydrogen ion is transmitted into ground water and to surface streams and lakes. Thus one effect of increased acid deposition is to increase cation concentrations, initially at least, in surface waters. These processes have been monitored in calibrated watersheds in Norway, Sweden, Canada, and the United States.

The extent to which acid deposition and alkalinity generation have reached a steady state over the long term is unknown. Over the short term, Plastic Lake is acidifying at current rates of acid deposition; about one-half of this lake's remaining alkalinity has been lost during the past eight years. In southern Quebec and Ontario, the acids in acid rain are about 90 per cent sulphuric and 10 per cent nitric. In response to this ionic composition, surface waters are changing from bicarbonate-based to dilute solutions of calcium sulphate, a neutral salt with no buffering capacity. In the lakes of south-central Ontario, sulphate concentration is elevated some four to eight times above normal concentrations. In Sweden and elsewhere in Europe, nitrate concentrations in surface waters have been increasing, with the associated concern for human health.

Acid rain has profound effects on masonry, statuary, bridges, piping, and other building materials. Of special concern to human health are the metals leached from lead, copper, and galvanized pipes, plus zinc and copper from brass pumps and taps, and lead from solder. The acidification of well waters has been manifest in increased metal concentrations both leached from the soils and from metal piping. In Sweden this has been recognized as a significant health hazard of still unknown dimensions. If water percolates to a depth of ten meters in thirty years, there may be many wells still in the process of acidifying. The corollary is that following a reduction in acid deposition from the atmosphere, there will be a long lag before acidified wells will return to higher pH and the associated lower concentrations of toxic metals.

Acid rain has now had centre stage for a decade: a decade of escalating new reports and rhetoric, both political and scientific. The controls on SO₂ emissions legislated for eastern Canada will not be implemented fully until 1994. In the worst-case scenario, U.S. emissions could rise by about the amount Canadian emissions are reduced, leaving acid deposition at about current levels, lower where smelter dominated, higher where of long-range transport in origin. In the best-case scenario, U.S. and Canadian emissions would decline lock-step to yield acid loadings below twenty kg per ha for Ontario and Quebec. However, the threshold of effects or "critical level" of acid deposition has yet to be defined.

In the absence of a United States-Canada agreement on transboundary air

pollution, it is a moot question if the political will to solve the acid rain problem can be maintained. Financial and technical resources are needed elsewhere. New environmental problems, such as "global warming," have titles even more compelling than acid rain. It remains to be seen if the concern over acid rain will pass before the problem is resolved, if acid rain is simply subsumed under a larger umbrella of global environmental problems, or if acid deposition can be reduced below the levels causing acidification of the environment.

Canada's Peatlands: Their Importance for the Global Carbon Cycle and Possible Effects of "Greenhouse" Climatic Warming†

CANADIAN peatlands (peat depth > 40 cm) cover 111 million ha, about 12% of the country's land area (1) and about one-third of the area of all northern peatlands. Much of Canada's peatland area lies in the zone of discontinuous permafrost (2). The largest single peatland region in North America, about 29 million ha, is that of the Hudson / James Bay Lowland (3). Data of Boville *et al.* (4), Riley (5), and Riley (personal communication) suggest that the mean depth of Canada's peatlands is about 2.1 m. Data of Tarnocai (1), Boville *et al.* (4), Riley (6), Riley and Michaud (7), and E. Gorham and J.A. Janssens (unpublished) suggest a mean bulk density of 112 g L⁻¹. Average carbon content is about 51.7% (6,7, and E. Gorham and J.A. Janssens unpublished). Combining these data gives a total carbon pool of 135 petagrams (1 Pg = 10¹⁵ g), which is about 11% of the global pool of 1200 Pg estimated for soil and organic detritus (8).

The average rate of accretion for Canadian peatlands, estimated from top to bottom of 121 ¹⁴C-dated peat cores (E. Gorham, J.A. Janssens and S.C. Zoltai, unpublished) is 0.51 mm yr⁻¹. Divided into a mean depth of 2.1 m, it indicates an average age of about 4,100 years. Multiplied by the bulk density and carbon percentage given earlier, this accretion rate amounts to 28 g m⁻² yr⁻¹, about 9% of net primary production by the plants of northern peatlands (9). Estimating that about 1% of Canada's peatlands are drained (10) and that perhaps 5% are too far north to accumulate peat at the present time (cf. 11), the remaining 104 million ha would accumulate about 0.03 Pg C annually if peat continues to be deposited presently at the average rate estimated above. This is only 0.6% of the 5 Pg C released annually by fossil-fuel combustion (8).

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Methane emissions from Canadian peatlands are not well characterized. However, data of Crill *et al.* (12) suggest rather little latitudinal variation in midsummer rates of emission. Their largest data base is for northern Minnesota, where midsummer emissions average $155 \text{ mg C m}^{-2} \text{ day}^{-1}$. Taking half that rate for an average period of 180 days yr^{-1} above 0°C , over an area of 104 million ha, yields annual carbon emissions of 0.015 Pg. If molecules of methane exert a warming effect twenty times that of carbon-dioxide molecules (13), this is equivalent to about 0.3 Pg of CO_2 -carbon. Assuming that Canadian peatlands cover about one-third of the total area of northern peatlands, and perhaps one-quarter of the world peatland area, methane emissions over these larger areas (if roughly similar in these other wetlands) are 0.9 and 1.2 Pg C, respectively. These amounts are appreciable in comparison to the 5 Pg contributed by combustion of fossil fuels (8).

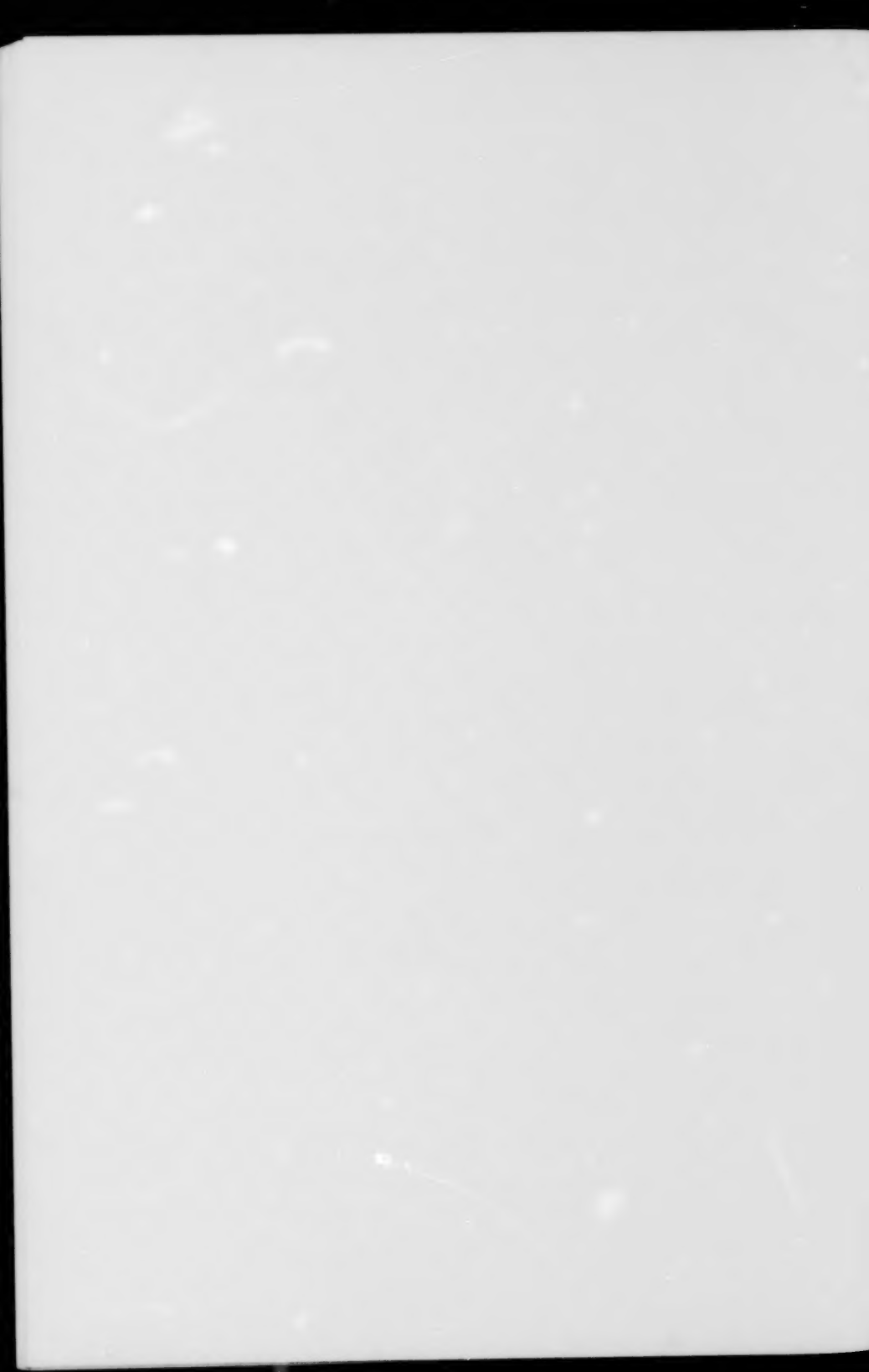
Potential effects of "greenhouse" climatic warming upon Canadian and other northern peatlands are very considerable and threaten severe biotic impoverishment (cf. 9). Those close to the southern border of Canada will probably dry out sufficiently to allow substantial erosion and peat oxidation. In the permafrost zone, melting may lead to substantial drawdown of peatland water tables and, again, increased oxidation. If as much as one-half of the total area of Canadian peatlands were to lose 1 cm of peat by oxidation annually, that would amount to a release of 0.3 Pg C yr^{-1} , about 6% of the carbon released annually by fossil-fuel combustion. Multiplying by 3 to cover all northern peatlands would make such a release of appreciable importance. However, the effects upon climate of such an increased release of carbon dioxide might be counterbalanced in two ways. First, drawdown of the water-table—if pronounced—would most likely reduce methane emissions from peatlands substantially (14). Second, in the permafrost zone there is the likelihood of considerable thermokarst erosion (15, 16) that will flood large areas and lead to renewed peat accumulation in them. Moreover, far northern peatlands that have not been accumulating peat for thousands of years (11) may again become active, sequestering carbon from carbon dioxide but also releasing methane. Thus the overall net effect of "greenhouse" warming upon the carbon budget of Canadian (and other) northern peatlands remains uncertain, and deserves major attention by ecosystem ecologists and biogeochemists.¹

REFERENCES

- 1 Tarnocai, C. 1984. *Peat Resources of Canada*. National Research Council of Canada, Publ. No. 24140, 17 pp. + 2 maps.
- 2 Brown, R.J.E. 1977. "Muskeg and permafrost." In *Muskeg and the Northern Environment in Canada*, ed. N.W. Radforth and C.O. Brawner, pp. 148–63.
- 3 Riley, J.L. 1982. "Hudson Bay Lowland floristic inventory, wetlands catalogue, and conservation strategy." *Naturaliste Canadien* 109:543–55.

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- 4 Boville, B.W., R.E. Munn, and F.K. Hare. Undated. *The Storage of Non-Living Organic Carbon in Boreal and Arctic Zones—Canada*. Final report, contract No. DE-AS01-81EV-10688, Department of Energy. Washington, D.C., 89 pp.
- 5 Riley, J.L. 1987. "The Ontario peatland inventory, 1982–86." In *Proc. Symposium '87, Wetlands/Peatlands*, ed. C.D.A. Rubec and R.P. Overend, Edmonton, Alberta, pp. 373–82.
- 6 Riley, J.L. 1987. *Peat and Peatland Resources of Northeastern Ontario*. Ontario Geol. Surv., Open-File Rep. No. 5631, 261 pp. + appendix and maps.
- 7 Riley, J.L., and L. Michaud. 1987. *Peat and Peatland Resources of Northwestern Ontario*. Ontario Geol. Surv., Open-File Rep. No. 5632, 275 pp. + appendix and maps.
- 8 Moore, B., and B. Bolin. 1986–87. "The oceans, carbon dioxide, and global climate change." *Oceanus* 29(4):9–15.
- 9 Gorham, E. In press. "Biotic impoverishment in northern peatlands." In *The Earth in Transition: Patterns and Processes of Biotic Impoverishment*, ed. G.M. Woodwell. Cambridge Univ. Press.
- 10 Kivinen, E., and P. Pakarinen. 1980. "Peatland areas and the proportion of virgin peatlands in different countries." In *Proc. Sixth Int. Peat Congr.*, Duluth, MN, pp. 52–54.
- 11 Zoltai, S.C., and F.C. Pollett. 1983. "Wetlands in Canada: their classification, distribution, and use." In *Ecosystems of the World, 4B, Mires: Swamp, Bog, Fen and Moor, Regional Studies*, ed. A.J.P. Gore, Elsevier, New York, N.Y., pp. 245–68.
- 12 Crill, P.M., K.B. Bartlett, R.C. Harriss, E. Gorham, E.S. Verry, D.I. Sebacher, L. Mazdar, and W. Sanner. 1988. "Methane flux from Minnesota peatlands." *Global Biogeochemical Cycles* 2:371–84.
- 13 Mooney, H.S., P.M. Vitousek, and P.A. Matson. 1987. "Exchange of materials between terrestrial ecosystems and the atmosphere." *Science* 238:926–32.
- 14 Harriss, R.C., D.I. Sebacher, and F.P. Day, Jr. 1982. Methane flux in the Great Dismal Swamp. *Nature* 297:673–74.
- 15 Billings, W.D., J.O. Luken, D.A. Mortensen, and K.M. Peterson. 1982. "Arctic tundra: a source or sink for atmospheric carbon dioxide in a changing environment?" *Oecologia* 53:7–11.
- 16 Billings, W.D., J.O. Luken, D.A. Mortensen, and K.M. Peterson. 1983. "Increasing atmospheric carbon dioxide: possible effects on arctic tundra." *Oecologia* 58:286–89.



Adverse Health Effects of the Precursors of Acid Rain†

WE NOW KNOW that acid rain is the end result of a complex series of events, originating in SO_2 and NO_x emissions; the formation of sulphuric and nitric acids when conditions are favourable (high humidity, high temperatures, slow wind drift, and the presence of ozone are thought to be important); neutralization of the acids by ammonia to form sulphates and nitrates; and final precipitation.

The precursors of acid rain are therefore: SO_2 ; oxides of nitrogen; ozone formed from the oxides of nitrogen in the presence of hydrocarbons; acidic aerosols; and sulphates and nitrates of variable acidity. In summer, over large portions of the Northeast United States and the southern regions of Quebec and Ontario, an acid summer haze is formed from these precursors. Visibility is reduced by the aerosol haze—and the visibility in kilometers is closely correlated with the sulphate aerosols present in the air in summer.

As far as we know, the actual acid rain does not directly affect human health, but, as I shall indicate, it is very probable that the same cannot be said of the precursors.

SULPHUR DIOXIDE

This directly emitted pollutant was one of the first air pollutants to be recognised as important. It is emitted from coal-burning generating plants in considerable volume, the most recent estimate being that emissions in the United States add up to about 27 million tons / year, of which about 7.9 million tons are emitted in EPA region 5 which includes Illinois, Indiana, Michigan,

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Minnesota and Ohio—regions which are upwind from southern Ontario. Concentrations have fallen over the past ten years; data from seventeen stations in southern Ontario indicate that whereas the mean hourly maximum observed concentration of SO_2 in 1974 was 3.97 parts per hundred million, by 1981 this had fallen to 1.86 parts per hundred million (1).

During the past few years, controlled exposures to SO_2 of normal subjects and those with asthma have shown that asthmatics are much more sensitive to this gas than others (2). A fall in maximal airflow occurs in concentrations of less than 0.5 parts per million in asthmatics but not in normals. Such concentrations might be encountered in a downdraft from a major stack of a generating plant, but would not be encountered nowadays in the general environment. Respiratory symptoms of cough and sputum production, and possibly wheezing illnesses, may be commoner in regions with higher SO_2 levels (3), but it seems unlikely that the levels now existing in Canada would cause direct adverse effects.

OXIDES OF NITROGEN

These are emitted from any combustion source. Emissions in the United States amounted to about 23 million tons in 1986, of which about 9 came from transportation sources, 8 came from electric generating plants, and 5 from non-utility combustion. Hourly maxima over southern Ontario in the summer have remained relatively constant, being 4.9 parts per hundred million in 1974, and 4.2 in 1983 (1).

These levels would not be associated with adverse health effects, but the annual rate misrepresents the risk from oxides of nitrogen, since very much higher concentrations are encountered when you stand at a busy traffic intersection in a downtown area waiting to cross the street, in conditions of still air. We have learned in the past few years that gas stoves may be the cause of high levels indoors; it has been shown that average kitchen levels in homes in the Boston area with gas cookers was 58.2 parts per billion, whereas in comparable homes with electric stoves it was 5.1 parts per billion (4). It is possible that the higher levels may be associated with increased respiratory illness in children—certainly the concentrations that may be inhaled when leaning over a gas stove might be high enough to cause effects in some people, since concentrations of 0.30 parts per million in asthmatics have been found to increase the general level of airway reactivity (5).

OZONE

Over southern Ontario in the summer, mean maximal hourly levels of oxone have ranged between 48 parts per million and 68 parts per million between 1974 and 1983. No general trend is detectable. Hourly maxima at individual stations have ranged up to about 200 parts per billion over the same period (1). It is

common for elevated ozone levels to persist for several hours when conditions are favourable for its formation and long-range transport.

We know more about the acute effects of ozone than we do about most pollutants. The ventilatory flow capability (FEV1) begins to be reduced after two hours of intermittent moderate exercise in 120 parts per billion (0.12 parts per million) (6); and airflow becomes progressively more impaired if exposure is continued for six hours (7). Recovery is relatively slow, taking several hours for values to return to control after exposure has ended. It is the ability to take a deep breath which first changes on ozone exposure, and this is probably caused by the stimulation of receptors in the human airway by the inflammatory reaction that ozone causes (8). The mechanism is different from that which induces airflow obstruction in asthmatics, since drugs which prevent that response have no effect on the change induced by ozone. It has been shown that asthmatic subjects are not more sensitive to ozone than normals, an observation that adds further support to the idea that the mechanism of ozone's action is essentially different from that of SO₂.

In studies of children in summer camp in the United States and in Canada, the average FEV1 level is closely related to the ozone concentration in which the children are active, even when the ozone concentration is below 120 parts per billion (9). Since we know that decrements in these function tests after ozone exposure are indicative of inflammation in the lung (a conclusion confirmed by recent studies [10]); that lung permeability is changed by ozone (11); and that ozone causes an increase in general airway reactivity, it would be unwise to dismiss changes in FEV1 as a transient reversible change of no long term significance.

ACID AEROSOLS AND SULPHATES

Ammonium sulphate is the commonest of the sulphates formed from SO₂. Its concentration over Ontario in the summer varies between 2 and 40 micrograms per cubic meter (1). These concentrations do not cause inflammation or irritation in the lung, and are lower than those to which asthmatic subjects are responsive.

We have recently become aware that H₂SO₄ aerosol occurs episodically in the summer over these regions. It was recorded at the children's summer camp in Dunville, Ontario in July 1986 by Spengler and his colleagues, and attained a concentration of 30 micrograms / m³ (12). By great good fortune, a similar aerosol analyser was then running at Scarborough just east of Toronto. On the same day (July 26th), a few hours later, it recorded a peak of 15 micrograms per cubic meter (13). The peak was associated with high levels of both ozone and ammonium sulphate. We have few observations to relate to these levels of this aerosol, and few measurements of the aerosol itself. However, we have just received the hospital admission data for July 1986, and a preliminary comparison between hospital admissions for that day and the two following

days, with comparable days in other years, does not show that the week including July 26, 1986 was strikingly different in terms of respiratory hospital admissions from corresponding weeks in the preceding nine years. We will need longitudinal studies of acidic aerosol and health data before we can be sure that this result is representative. Those studies can only be done when routine monitoring of sulphuric acid aerosol is in place.

Spengler has shown that peaks of sulphuric acid aerosol occur in the summer in Steubenville, Ohio and in Kingston, Tennessee (12). We know little of the factors responsible for the persistence of this acidic aerosol, but presumably absence of ammonia is one; it has been speculated that southern Ontario may constitute a special environment as the pollutants can travel over water (which emits no ammonia) while the formation of sulphuric and nitric acids is occurring. Spengler has calculated that the delivered dose of sulphuric acid in these episodes is not much lower than the delivered dose shown in controlled studies to depress the FEV1 in asthmatics (12).

EPIDEMIOLOGICAL EVIDENCE OF ADVERSE HEALTH EFFECTS

Epidemiological studies can be conducted only when continuous monitoring data is available. Our studies of the acid summer haze effect in southern Ontario (1) have shown that hospital admissions in the region in summer for acute respiratory conditions (but not for non-respiratory conditions) are associated with increased levels of ozone and, most particularly, sulphates. This association has held over a nine-year period. It is possible to show that actual respiratory admissions are higher when ozone levels are above 80 parts per billion, compared to when they are below that level. Furthermore, the relationship between pollutants and acute respiratory admissions is still present when the category of "asthma" is excluded, probably indicating that categories of illness such as bronchitis and bronchiolitis are also involved. This conclusion may be related to the observations that oxidant exposures reduce the ability of mice to resist bacterial aerosols to which they are subsequently exposed.

It is very possible that ozone and sulphates (which are closely correlated in summer in this region (" r " = 0.646)), are both surrogates for H_2SO_4 aerosol. We will need more data to study this possibility (17). The levels of sulphuric acid aerosol being recorded are lower than those believed to have occurred in major episodes in London thirty years ago, when it is probable that values may have exceeded 500 micrograms per cubic meter. Such levels would be associated with observable changes in immediate mortality.

A different analysis of Ontario data has just been published in a report from Ontario Hydro (14). Analysing morbidity (hospital admission) data and mortality from respiratory diseases in different counties in Ontario, it was shown that both of these were significantly associated with levels of both SO_2 and sulphates. This careful study by Plagiannakos and Parker took account of

differences between the counties in alcohol and smoking consumption, as well as data for socio-economic status. Their conclusions confirm the association between daily hospital admission rates and air pollutants in the summer which we have reported (1).

Elevated ozone levels somewhat higher than those that occur in southern Ontario have, in Los Angeles, been shown to be associated with worsening of asthma (15). The asthmatic state is difficult to define and characterize, but it is clear that a significant segment of the "normal" population may have a heightened response to inhaled physiological substances (such as histamine and methacholine) although they do not suffer from clinical asthma. We do not know how to interpret these observations, but it is of interest that a recent comparison of normal schoolgirls aged between seven and eleven years at a summer camp in Ontario, with an equivalent group in New Zealand, conducted by the same investigators, found that the prevalence of an increased response to methacholine in the Ontario girls was 32%; in New Zealand it was present in 18% (16). We do not know the significance of that difference, but it is unsettling, since possibly living in an environment with episodic increases in ozone and sulphuric acid might have the effect of heightening the bronchoconstrictor response. We do know that hospital admission rates for asthma have increased in Canada and in many other parts of the world. Increases have occurred in Ontario and Quebec, but also in the prairie provinces where the ozone and sulphuric acid levels are very low. (17).

CONCLUSIONS

This brief summary of a great deal of epidemiological and experimental observation clearly indicates that the precursors of acid rain, taken together, at their present concentrations are very likely to be already responsible for adverse health effects. To conclude that they are not responsible for any such effects, would entail the following decisions:

- 1 that the adverse effects of ozone have no long-term consequences;
- 2 that the evidence of greater airway reactivity in children in Ontario compared to a similar group in New Zealand can be ignored;
- 3 that the demonstrated association between hospital admissions for respiratory diseases in summer in southern Ontario (which does not apply to non-respiratory conditions) is a coincidence or due to unidentified confounders;
- 4 that the association between sulphate levels and respiratory mortality and morbidity in Ontario is also coincidental;
- 5 that the evidence that relates NO_2 and ozone to increased airway reactivity can be ignored; and
- 6 that the increased hospital admissions for asthma are unrelated to pollution levels.

I have deliberately stated these positions in this way because, for reasons I have not been able to determine, since they are never explicitly stated, Canadian Health officials have not advised politicians that there are serious grounds for believing that the precursors of acid rain are already affecting the health of Canadians and Americans. At a recent conference on acid rain in Los Angeles, I heard Senator George Mitchell, whose Bill on Acid Rain is before the U.S. senate, state that his committee had heard such evidence on the adverse health effects of the precursors of acid rain, and that they were convinced that these effects were already occurring. I think this judgment is correct.

I should note that some of the arguments depend on the much-debated question of causal inference from associative data in epidemiological studies; a recent volume on this issue has provided a useful review of the issues (18). We should, however, recall the observation of Sir Austin Bradford Hill (whose criteria for causality are often quoted): "If we cannot detect (a confounding variable) or reasonably infer a specific one, then we are entitled to reject the vague contention of the armchair critic 'you can't prove it, there may be such a feature'" (19).

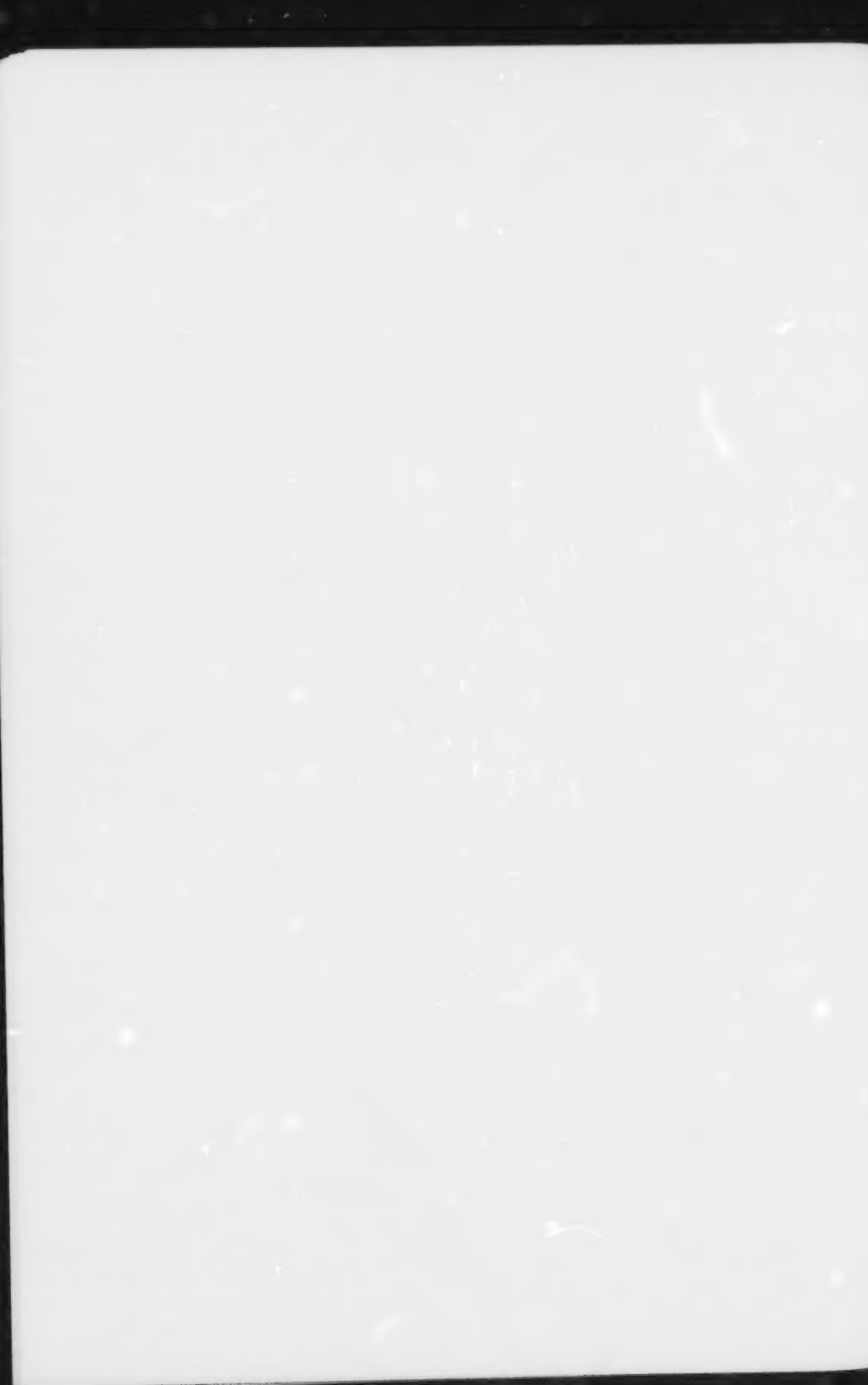
Concordance of data from different types of observation is very important, as has been noted by the authors of the recent Ontario Hydro study (14). A similar study to ours is now being organized in upper New York State by research workers at the NYU Environmental Sciences Center in Tuxedo. The new U.S. / Canadian study of the health of schoolchildren in different regions of the United States and Canada with different exposure profiles will, if it is negative, reassure us that ozone and summer acidic aerosols are without a detectable effect on that important age group.

We are proud of our tradition that people are innocent until proven guilty. Yet in environmental matters this tradition has been found to be a bad guide. I suggest that we have enough data at this point to state that present levels of acid rain precursors should be presumed to be dangerous until further studies have shown them to be innocent.

REFERENCES

- 1 Bates, D.V. and Sizto, R. Air Pollution and Hospital Admissions in Southern Ontario: The Acid Summer Haze Effect *Environ Research* 43, 317-31, 1987.
- 2 Bethel, R.A., Epstein, J., Sheppard, D., Nadel, J.A., and Boushey, H.A. Sulfur Dioxide-induced bronchoconstriction in freely breathing, exercising asthmatic subjects. *Am Rev Respir Dis* 128, 539-44, 1983.
- 3 Charpin, D., Kleisbauer, J.P., Fondarai, J., Graland, B., Viala, A., and Gouezo, F. Respiratory symptoms and air pollution changes in children: the Gardanne coal-basin study. *Arch Environ Health* 43, 22-27, 1988.
- 4 Ryan, P.B., Soczek, M.L., Spengler, J.D., and Billick, I.H. The Boston residential NO₂ characterization study: I. Preliminary evaluation of the survey methodology. *J. Air Pollut Control Ass* 38, 22-27, 1988.

- 5 Bauer, M.A., Utell, Morrow, P.E., Speers, D.M., and Gibb, F.R. Inhalation of 0.30 ppm nitrogen dioxide potentiates exercise-induced bronchospasm in asthmatics. *Am Rev Respir Dis* 134, 1203-08, 1986.
- 6 McDonnell, W.F. III, Chapman, R.S., Leigh, M.W., Strobe, G.L., and Collier, A.M. Respiratory responses of vigorously exercising children to 0.12 ppm ozone exposure. *Am Rev Respir Dis* 132, 875-879, 1985.
- 7 Folinsbee, L.J., McDonnell, W.F., and Horstman, D.H. Pulmonary function and symptom responses after 6.6 hour exposure to 0.12 ppm ozone with moderate exercise. *J Air Pollut Control Ass* 38, 28-35, 1988.
- 8 Hazucha, M.J., Bates, D.V., and Bromberg, P.A. Mechanism of action of ozone on the human lung. Submitted for publication *J Appl Physiol* May 1988.
- 9 Spektor, D.M., Lippmann, M., Lioy, P.J., Thurston, G.D., Citak, K., James, D.J., Bock, N., Speizer, F.E., and Hayes, C. Effects of ambient ozone on respiratory function in active, normal children. *Am Rev Respir Dis* 137, 313-20, 1988.
- 10 Fouke, J.M., Delemos, R.A., and McFadden, E.R. Jr. Airway response to ultra short-term exposure to ozone. *Am Rev Respir Dis* 137, 326-30, 1988.
- 11 Kehrl, H.R., Vincent, L.M., Kowalsky, R.J., Horstman, D.H., O'Neil, J.J., McCartney, W.H., and Bromberg, P.A. Ozone exposure increases human respiratory epithelial permeability in humans. *Am Rev Respir Dis* 135, 1124-28, 1987.
- 12 Spengler, J.D., Keeler, G.J., Koutrakis, P., and Raizenne, M. Exposure to acidic aerosols In: *International Symposium on the Health Effects of Acid Aerosols: addressing obstacles in an emerging data base* October 1987: Research Triangle Park, NC. Environmental Health Perspectives (In Press).
- 13 Thurston, G.D., and Waldman, J. Acid aerosol transport episodes in Toronto, Ontario. Presented at 80th Annual Meeting of the Air Pollution Control Association; New York, NY. Pittsburgh, PA: Air Pollution Control Association paper No. 87-89.9.
- 14 Plagiannakos, T., and Parker, J. An assessment of Air Pollution effects on human health in Ontario Energy Economics Section, Economic and Forecasts Division, Ontario Hydro: File No: 706.01 (#260) (700 University Avenue Toronto, ON M5G 1X6).
- 15 Whittemore, A.S., and Korn, E.L. Asthma and air pollution in the Los Angeles area. *Am J Pub Health* 70, 687-96, 1980.
- 16 Fitzgerald, A.M., Sears, M.R., Roberts, R.S., Morris, M.M., Fester, D.A., and Hargreave, F.E. Symptoms of asthma and airway hyperresponsiveness to methacholine in a population of Canadian school children. *Am Rev Respir Dis* 137, 285, 1988 (Abstract).
- 17 Bates, D.V., and Sizto, R. The Ontario Air Pollution Study: Identification of the causative agent. *Environ Health Perspectives*. (In press 1988).
- 18 Causal inference. Edited by Kenneth J. Rothman. 1988. Epidemiology Resources Inc., PO Box 57, Chestnut Hill, Mass 02167.
- 19 Hill, A.B. The environment and disease: Association or causation? *Proc Roy Soc Med* 58, 295-300, 1965.



Effects of Climate Change on the Great Lakes[†]

HERE IN WINDSOR we know that there has been climate change in the past. Some 200 million years ago the site of our meeting lay at the bottom of a warm tropical sea. For thousands of years, during the Pleistocene glaciation, it was covered with a great depth of ice, and only ten thousand years ago it lay at the bottom of a glacial lake. All of these changes occurred without man's influence.

What is different in the talk of climatic change today is the idea that humans are causing changes in the atmosphere that may significantly alter the climate. Fifteen years ago we heard a great deal about two schools of thought regarding man's impact on climate. The "particle cooling effect" school hypothesized that particulates added to the atmosphere by man would decrease incoming solar radiation and cause decreased world surface temperatures.

On the other hand the "CO₂ warming effect" school hypothesized that increasing amounts of CO₂ and similar gases put into the atmosphere by human activity would allow solar radiation to reach the earth unchanged but would absorb the long wave radiation emitted by the earth and re-radiate it (as does greenhouse glass) back to the earth's surface, thus increasing surface temperatures.

The actual record of world temperatures (Figure 1) lends credence to both points of view. The earth's temperature record (mostly from northern hemisphere stations) shows that since records began in the late 1800s there were increasing temperatures during the period from 1920 to 1950 and a decreasing trend from 1950 until 1970, with a slight increase since 1970. However, more

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† Presented at the symposium, "Future Changes and Challenges to Canadian Water Resources," University of Windsor, 6 June, 1988.

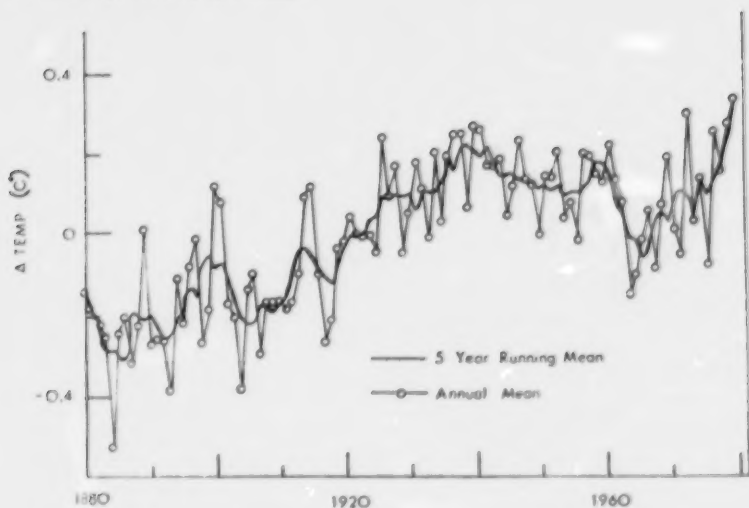


FIGURE 1. World Temperatures, 1880-1980 (after Hansen).

recently the "Greenhouse Effect" school has been gaining in popularity and, at the present time, a consensus is emerging among world climatologists that climatic warming will occur (World Meteorological Organization 1986).

One result of this consensus was that national climate programs were set up in many countries. Canada's Atmospheric Environment Service (AES) established such a program and has funded research on the impact of possible climate warming in Canada and especially on Canadian economic activities. Results of these studies are being published by AES in a "Climate Change Digest" series, including the research discussed in this paper (Sanderson 1987).

The University of Windsor's Great Lakes Institute (GLI) was given a contract by the AES to study the effect of projected climatic change on Great Lakes levels and the impact on navigation and hydro-electric power development (Marchand *et al.* 1988). A further grant from the Donner Canadian Foundation has made it possible to continue this Great Lakes level research (Sanderson and Wong 1987).

What are the facts of the Greenhouse Effect? We know that the concentration of CO_2 in the atmosphere is increasing. Data from Mauna Loa in Hawaii, the South Pole, and more recently other stations (shown in Figure 2) indicate a steady increase in CO_2 concentrations. It is believed that pre-industrial concentrations were approximately 275 ppm. At present, levels are 340 ppm, and predictions are now being made that a doubling of CO_2 (over pre-industrial levels) will occur before the middle of the next century.

The impact of these increases in atmospheric CO_2 on world climates has been predicted by general circulation models. These GCM's are attempts to simulate

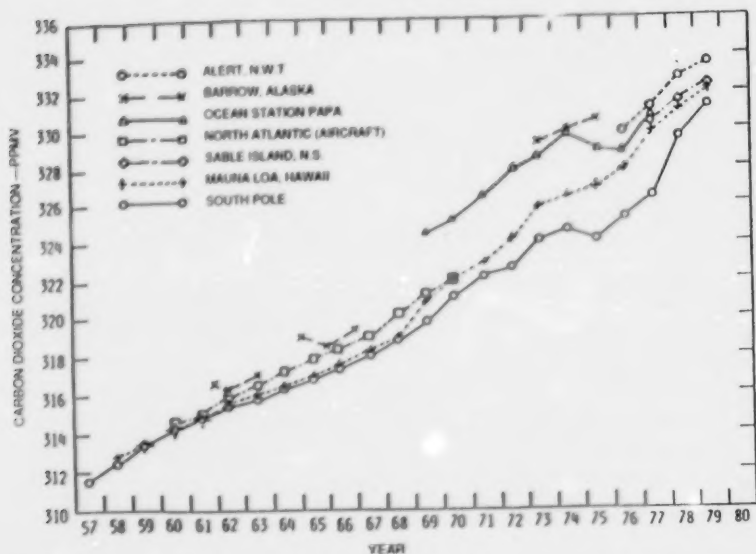


FIGURE 2. Secular changes in the concentration of atmospheric carbon dioxide (Bruce, 1984).

the three-dimensional circulation of the world's atmosphere. The models are very complex and contain a great many generalizations and assumptions. They also require huge computers, so few GCM's exist, two of the better known being the Geophysical Fluid Dynamics Laboratory or GFDL (Princeton) model and the Goddard Institute of Space Studies or GISS (Colorado) model.

For our work at the GLI, we were provided with the output of the GISS and GFDL GCM's. Since these are world models, with output data for a very coarse grid, it is difficult to use the output for a relatively small region like the Great Lakes Basin. For example, Figure 3 shows that only 10 grid squares (thus 10 data points) are provided by the GISS scenario for the Great Lakes Basin.

Table 1 presents the data on temperature and precipitation (from the GISS model) for two points in the Great Lakes Basin. Point 1 is in the northwestern and point 10 in the southeastern part of the basin. Average monthly temperatures for the period 1951-1980 are given in column (1), the change projected by the model in column 2, and the projected 2x CO₂ temperatures in column 3. For precipitation, the percentage changes from normal or average conditions are given. It will be seen that monthly temperatures projected by the GISS model show average increases of greater than 4°C (more in winter, less in summer). Precipitation is seen to increase in the northwest part of the basin (point 1) and decrease in the southeast part of the basin (point 10).

As an example of the 2x CO₂ climate in the Great Lakes basin Figure 4 shows



FIGURE 3. GISS data points in Great Lakes Basin.

average temperatures for January. Figure 4a shows the present 1951–1980 average temperatures over the basin, ranging from -5°C in the south to -20°C in the north. Figure 4b shows the projected (GISS) $2\times\text{CO}_2$ climate. If this scenario is realized, average temperatures in most of Southern Ontario in January will be above freezing. To put this in perspective, Southern Ontario would have a climate similar to the present one in Kentucky.

Our next problem was to translate these climate changes to the hydrologic regime of the Great Lakes. The Great Lakes are a gift of the Pleistocene glaciation which hollowed out the basins (perhaps already existing as down faults in the earth's crust), and these depressions filled with fresh water which today totals about 20% of the world's supply of fresh water. However it is well to keep in mind that all of this water is not renewable. Only the top few metres enter the hydrologic cycle and can be considered a renewable resource. Economically the region is a very important area for Canada and the United States; it contains some 35 million people, including one-third of the population of Canada.

For our project, the most important aspects of the lakes are the changing levels: Figure 5 shows mean annual levels for all the lakes since 1900. (The levels and flows on the lakes have been measured by federal agencies in the

TABLE 1
Present and Projected Future Mean Monthly Temperature and Precipitation in the Great Lakes Region (Grid points 1 and 10)

	(1) Temperature °C			(1) Precipitation (cm)			(10) Temperature °C			(10) Precipitation (cm)		
	Norm	CH	2 × CO ₂	Norm	Effect	2 × CO ₂	Norm	CH	2 × CO ₂	Norm	Effect	2 × CO ₂
Jan	-20.2	5.6	-14.6	1.2	117.6	1.4	-4.5	5.6	1.1	2.4	104.2	2.5
Feb	-17.5	5.6	-11.9	1.1	116.7	1.2	-5.5	5.1	-0.4	2.7	104.2	2.8
Mar	-9.5	5.3	-4.2	1.2	109.7	1.3	-2.5	4.8	2.3	3.2	100.0	3.2
Apr	0.2	4.5	4.7	1.4	107.7	1.5	4.5	4.5	9.0	3.5	100.0	3.5
May	7.8	3.6	11.4	2.1	103.2	2.2	13.0	4.0	17.0	3.4	100.0	3.4
Jun	14.5	3.0	17.5	3.0	110.0	3.3	18.0	3.8	21.8	3.3	103.3	3.4
Jly	17.0	2.9	19.9	3.0	111.1	3.3	21.0	4.0	25.0	4.0	103.8	4.2
Aug	14.8	3.1	17.9	2.9	113.0	3.3	18.5	4.3	22.8	3.7	95.2	3.5
Sep	9.5	3.7	13.2	2.9	110.0	3.2	15.0	4.4	19.4	3.3	77.8	2.6
Oct	4.0	4.6	8.6	2.1	116.7	2.5	10.0	4.5	14.5	3.2	70.0	2.3
Nov	-6.0	5.2	0.8	1.8	123.5	2.3	1.5	5.0	6.5	3.3	78.3	2.5
Dec	-15.5	5.5	-10.0	1.3	123.5	1.6	-4.0	5.6	1.6	2.4	88.0	2.1
Mean		4.4			113.5			4.6			93.7	

NORM = 1951-80 normals

CH = magnitude of change between 1951-80 normals and 2 × CO₂ normal

2 × CO₂ = projected normals under 2 × CO₂ conditions

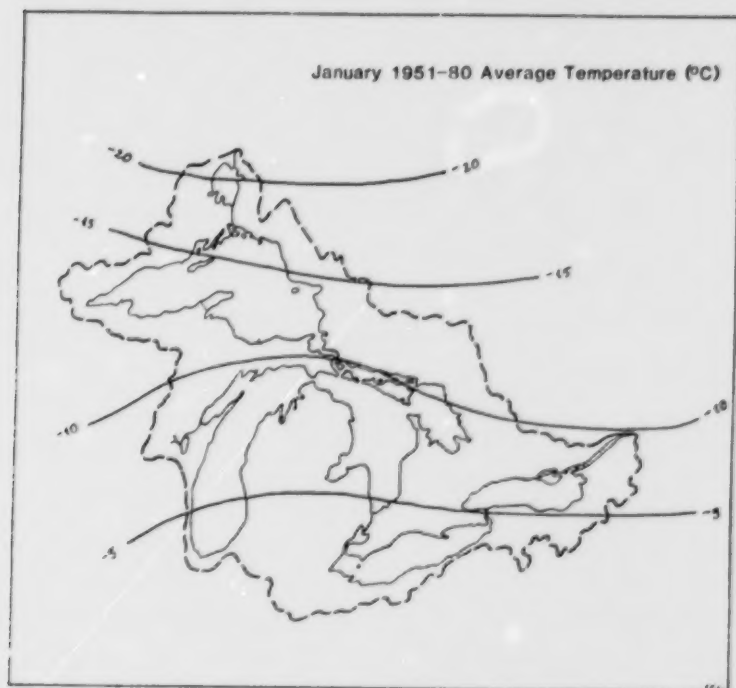


FIGURE 4a.

United States and Canada since about 1860.) Not shown on the graph are the seasonal fluctuations in levels, from high in summer to low in winter, amounting in an average year to about 30–40 cm. Superimposed on these seasonal changes are long-term fluctuations amounting to very great changes in levels of about two metres. There were periods of low levels in the 1930s and 1960s, high levels in the 1950s, and record-breaking high levels in the 1980s.

The causes of the changing levels are climatic, the primary parameters being precipitation on the lakes, evaporation from the lakes, and runoff from the watershed (as seen in Figure 6 for Lake Erie). Monthly mean water levels are seen in the top graph. The centre graph shows that precipitation is fairly uniform through the year but that evaporation is insignificant in the winter and spring, and rises to a maximum in fall. Runoff on the other hand is at a maximum in spring (with the snow melt) and falls to a minimum in fall. The sum of these three parameters, $P - E + RO$ is given the term "net basin supply" (NBS), the amount of water contributed by the lake and its basin to the overall hydrologic system. For Lake Erie the NBS is positive during the first half of the

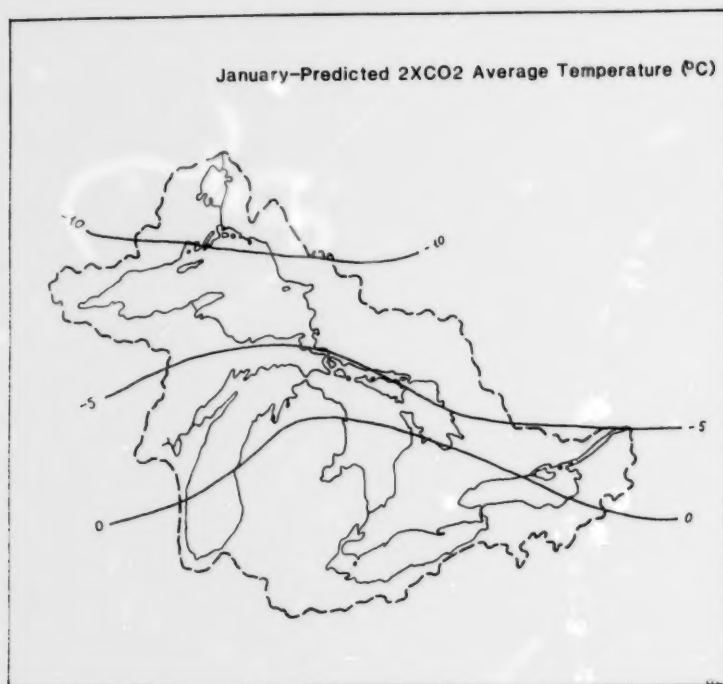


FIGURE 4b.

year, but actually negative (withdrawing water) from the system during late summer and fall. The yearly net basin supply of Lake Erie averages about 75 cm.

This hydrologic system can be modelled; at the GLI we used models provided by the Great Lakes Environmental Research Laboratory in Ann Arbor, Michigan. These included a large basin runoff model which is used to simulate runoff from the land area of each basin, using data on insolation, precipitation and temperature, and estimating evapotranspiration. Another model used data on precipitation over the lake estimated from shore stations, and evaporation from the lake estimated from mass transfer models, to obtain a net basin supply model for each lake. Finally a Great Lakes Hydrologic Response Model was used which combines the results of the above models to provide monthly levels of each lake and the flows in the connecting channels (Hartmann 1988).

Figures 7–10 show our results, again using Lake Erie as an example. Figure 7 shows runoff. BOC in each case is the historical situation—what actually occurred during the period 1956–1983. Scenario A gives the GFDL Model and

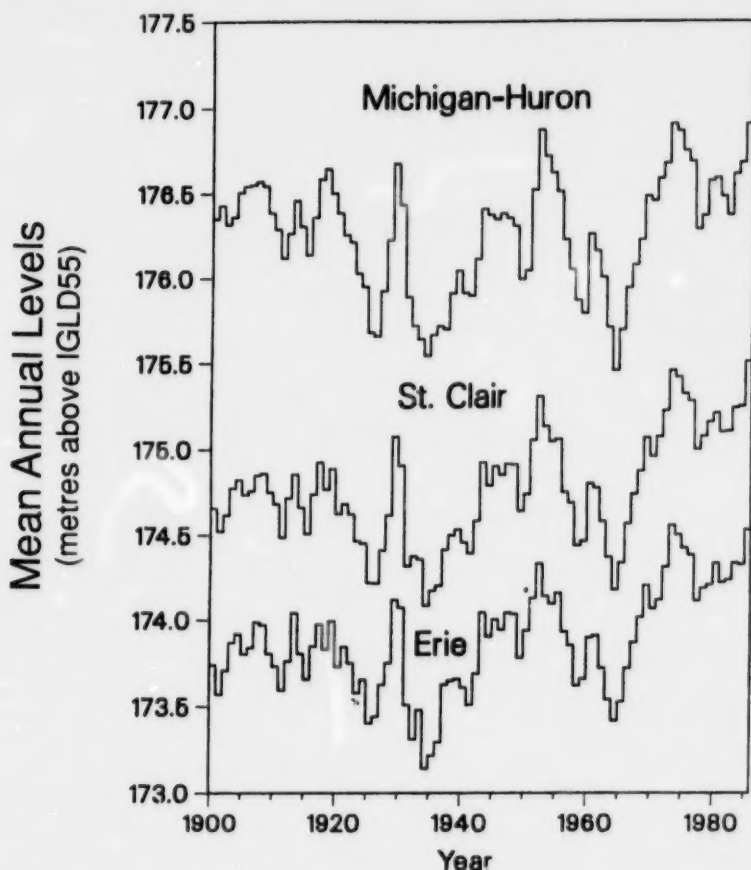


FIGURE 5. Mean annual water levels of Lakes Michigan-Huron, St. Clair, and Erie for 1900–1985.

scenario B the GISS Model results. Both scenarios indicate decreased runoff because of higher evapotranspiration from land areas due to increased temperatures.

Figure 8, presenting the precipitation data, shows a rather confused picture, since the models are not very consistent in predicting higher or lower precipitation under a $2 \times \text{CO}_2$ climate. Figure 9 (evaporation) shows that for both scenarios evaporation will be similar to that at present for the first half of the year. However, evaporation will be greatly increased in fall and winter under both scenarios because of warmer water temperatures.

Summing the three parameters gives the net basin supply shown in Figure 10.

LAKE ERIE

AVERAGE ANNUAL VARIATIONS (MONTHLY MEAN WATER LEVELS)

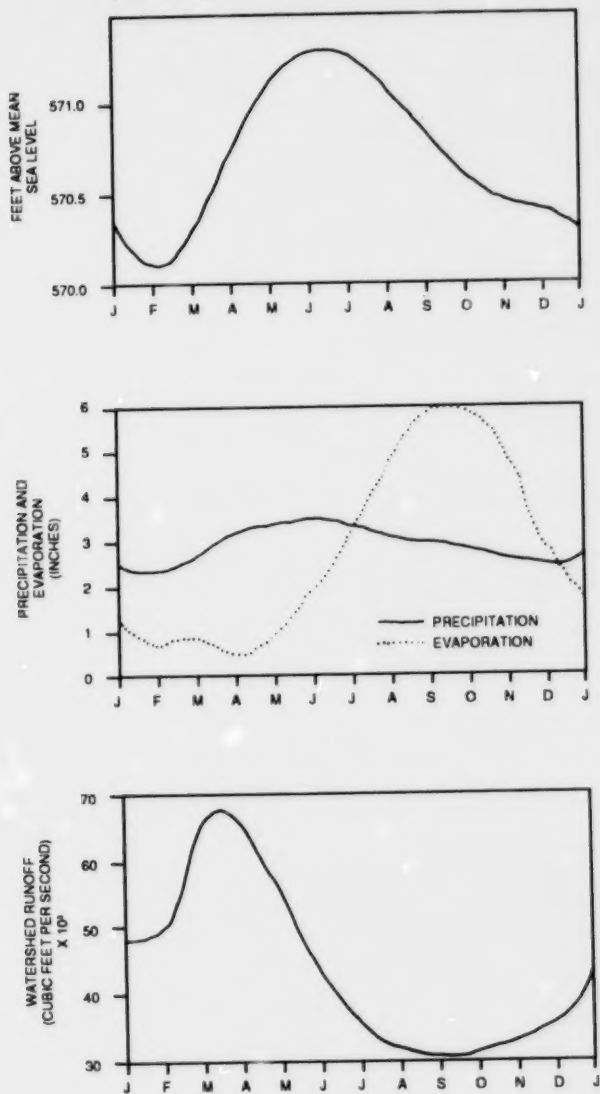


FIGURE 6.

Lake Erie Basin Runoff

(Monthly Averages 1956-1983)

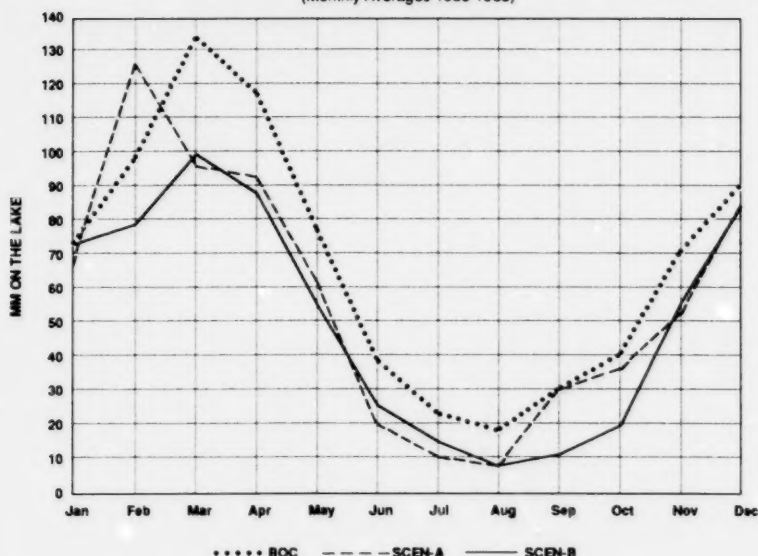


FIGURE 7.

Net basin supply is decreased under both scenarios especially in the late summer and fall. The amount of reduction for each lake is seen in Table 2. In Lake Erie, this amounts to 17% for the GFDL and 32% for the GISS scenario.

Figure 11 shows the resulting levels for Lake Erie. The top line shows the historical lake levels for the period 1900–1978; the middle line (assuming that climate variability will be the same under a 2x CO₂ climate as at present) indicates what would have happened to lake levels during the period 1900–1978 under the GISS climate scenario. The bottom line adds the scenario of increased consumptive use of Great Lakes water as projected by a study done by the International Joint commission. (Consumptive use refers to water that is withdrawn from a lake but not returned, as for example in industry or irrigation.) Under the GISS scenario, the average Lake Erie level would drop 40 cm and the probability of extreme low levels (as in the 1960s) would increase to 28% of the time. Under the GISS scenario, and adding increased consumptive use, the average level would be 70 cm lower than present and the probability of extreme low levels would increase to 70% of the time.

With the hydrologic models described above, we can add any other scenarios, such as diversions into or out of the lakes. One such diversion into the lakes that we often hear about is the Grand Canal scheme involving a diversion of 1560 M³/sec from James Bay into Lake Huron. With this diversion

Lake Erie Over Lake Precipitation

(Monthly Averages 1956-1983)

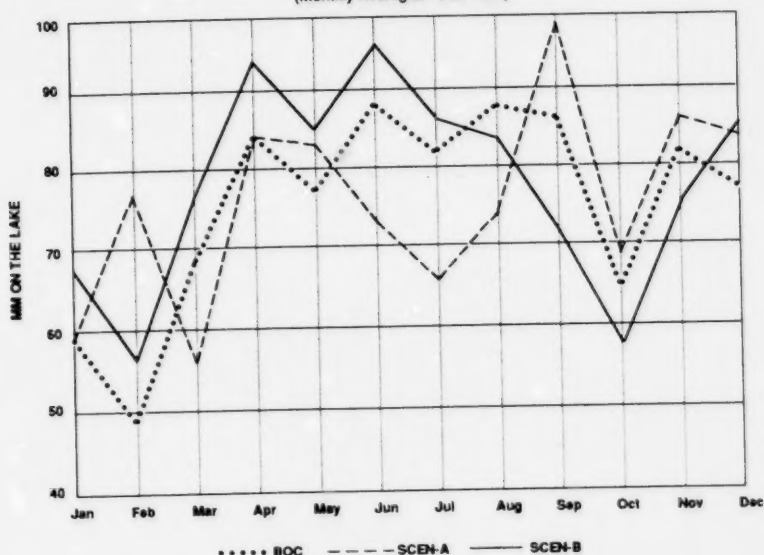


FIGURE 8.

and climatic change, Lake Erie levels would be approximately 20 cm higher than historical levels under the GFDL scenario, but levels would be restored to historical levels if the GISS scenario were to occur.

The Great Lakes Institute research for the Atmospheric Environment Service also involved the impact of climatic change on socio-economic factors in the Great Lakes. We looked at the impact of climatic change on navigation and hydro-electric power development. As an example of our results, I will briefly describe some of the effects on navigation.

We looked at the relationship between lake levels and cargos carried by the Canadian Great Lakes fleet. The four main cargos are iron ore, grain, coal, and limestone. The shipping companies load their ships to the maximum capacity based on the water levels. We found that for every inch reduction in lake level there is a 240-tonne loss of cargo that can be carried. Table 3 shows our results for the GISS scenario, with an average reduction in the level of Lake Erie of 70 cm. We found that the average navigation costs for the period 1900-1977 were \$197.3 million. With the projected climate change of the GISS scenario, and because of the increased number of trips required to carry the projected cargo, this would rise to \$206.9 million. Adding the predicted increase in consumptive use of Great Lakes water, the costs increased to \$262.2 million (an increase over current average costs of approximately 30%). We found that the frequency

Lake Erie Over Lake Evaporation

(Most Monthly Averages)

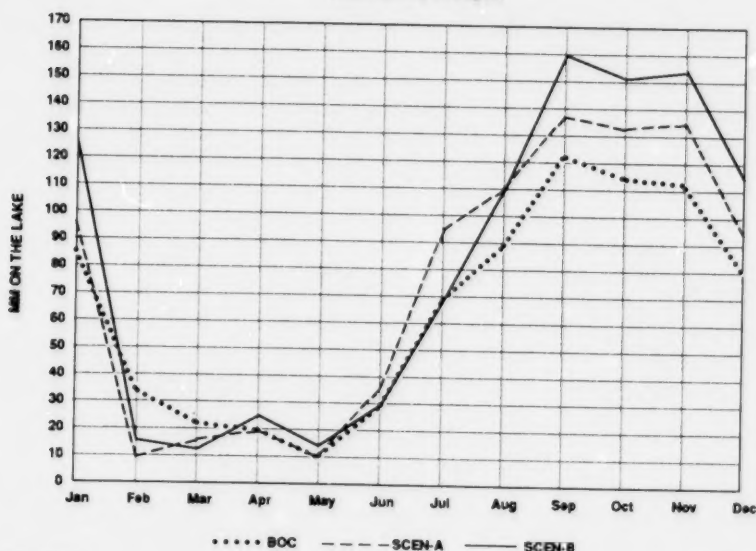


FIGURE 9.

of years when shipping costs would equal or exceed those of the low level period of 1963–1965 was nine years out of ten.

We found that average maximum ice cover on the lakes under the GISS scenario of future climatic change would decline from 72% to 0 for Lake Superior, 38% to 0 for Michigan, 65% to 0 for Huron, 33% to 0 for Ontario, with only Lake Erie projected to experience any ice cover (reduced from 90% to 50%). Such change would probably permit an eleven-month ice-free shipping season.

TABLE 2

Decrease in net basin supply under two climatic change scenarios

	Basin of comparison	GFDL	GISS
Lake Superior	100	86.6	78.3
Lake Michigan	100	80.6	62.2
Lake Huron	100	82.6	69.5
Lake St. Clair	100	82.5	68.6
Lake Erie	100	75.4	61.1
Lake Ontario	100	88.0	67.5
Average	100	82.6	67.9

Lake Erie Net Basin Supply

(Monthly Averages 1956-1983)

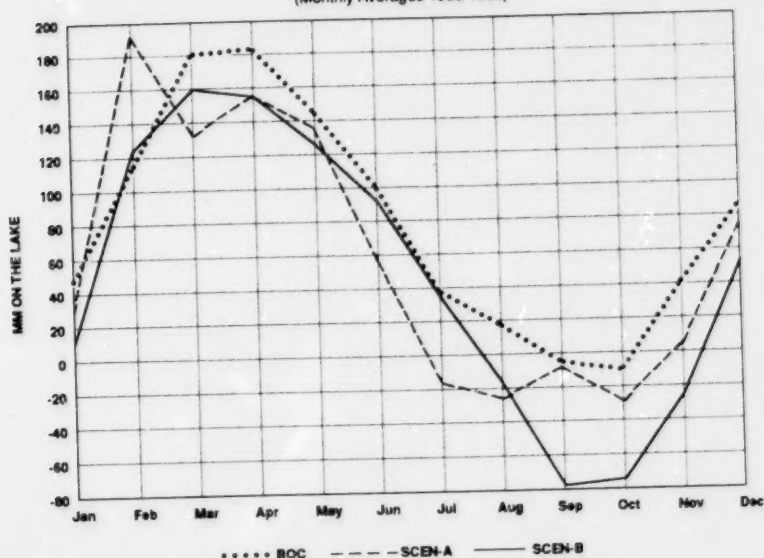


FIGURE 10.

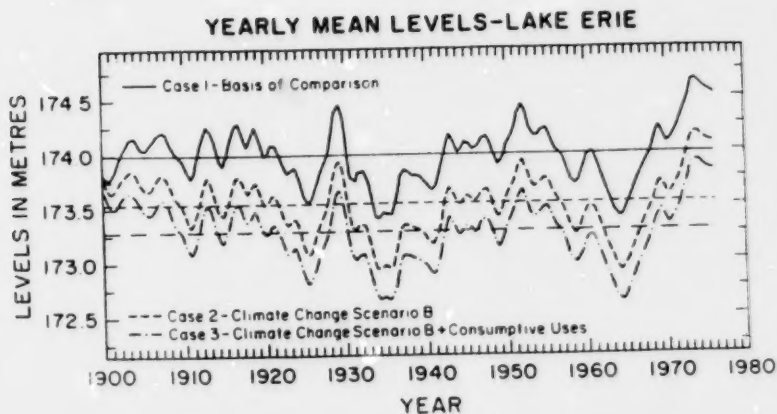


FIGURE 11.

TABLE 3

Annual navigation costs—Canadian fleet (1979 U.S.\$ × 1,000,000)

	Scenario 1 BOC (1900–77)	Scenario 2 Climate Change	Scenario 3 Climate Change & c.u.
Iron Ore	78.8	84.0	86.6
Grain	77.7	80.0	75.7
Coal	31.4	33.2	91.6
Limestone	9.6	9.7	8.3
Total	197.3	206.9	262.2

What conclusions can be drawn from these studies on climatic change and Great Lakes levels? First, we must remember that only two general circulation model scenarios were used, and that the models are continually being refined and new results released. However, the two we used, being relatively conservative, may represent the most probable scenarios. Some models have predicted more than a two-metre decline in lake levels.

Secondly, there are many uncertainties in the net basin supply models. There is much we do not know about over-water precipitation, lake heat storage, and over-water evaporation. However, these models do permit us to ask "What if?" and are valuable in estimating, at least crudely, the impact of various possible climatic changes and diversions on the levels of our Great Lakes.

And finally, our studies of the impact of possible climatic change on economic activity in the Great Lakes suggest that the transportation, energy, recreation, and other sectors of the economy, should take into consideration the likelihood that the future may not resemble the past in the Great Lakes.

REFERENCES

- Bruce, J.P. 1984. *Great Lakes Levels and Flows: Past and Future*. *Journal Great Lakes Research*. 10, 126–34.
- Hansen, J. et al. 1983. *Climatic Effects of Atmospheric CO₂ Science*. 223, 873–75.
- Hartmann, H.C. 1988. *Potential Variations of Great Lakes Water Levels: A Hydrologic Response Analysis*. Great Lakes Environmental Research Laboratory, Ann Arbor, Michigan NOAA Tech. Mem. ERL GLERL-68.
- Marchand, D., M. Sanderson, D. Howe and C. Alpaugh, 1988. *Climatic Change and Great Lakes Levels, the Impact on Shipping*. *Climatic Change* 12, 107–33.
- Sanderson, Marie, 1987. *Implications of Climatic Change for Navigation and Power Generation in the Great Lakes*. *Climate Change Digest*, Atmospheric Environment Service, Environment Canada CCD 87–03.
- Sanderson, M. and L. Wong, 1987. *Climatic Change and Great Lakes Water Levels*. The Influence of Climate Change and Climatic Variability on the Hydrologic Regime and Water Resources (Proc. Vancouver Symposium August 1987) IAHS Publ. #168.
- World Meteorological Organization, 1986. *Report of the International Conference on the Assessment of the Role of CO₂ and other Greenhouse Gases in Climate Variations and Associated Impacts*. Villach, Austria. October 1985 WMO Report #661.

Water at Risk: The Future Challenges for Canada's Water Resources[†]

WHILE IT is not wise to treat any part of the environment, especially water, in isolation, water is a good lens through which to view the state of our environment. Water is the element that binds us together and dictates where there can be life and where there will be desert. It is the liveblood of our environment, central to such diverse issues as pollution and food production.

In Canada we have tended to look north to see a blue and green wilderness of endless lakes and rivers surrounded by deep forests, and to think that we can never run out of water, even in a world which is outstripping its natural resources. This is a dangerous myth. It is time to replace it with a more realistic appreciation.

We all know the story of little Dutch boy who put his finger in a dyke to stop his land from being flooded. He became a hero for saving his people from one kind of water disaster. The time has come when courageous people are going to have to step forward to plug another kind of leak—the steady loss of fresh, clean water sources across the nation. We are facing increasing shortages of this most precious resource, and the situation is getting worse. The loss of many uses of fresh water because of pollution and excessive demand in one part of the country after another is amounting to a major drain on our economy.

The ongoing disaster of water shortages in the Prairies is simply the most newsworthy of our water problems today. The daily reports of a growing drought crisis indicate that we are developing a homegrown Sahel that will give us a taste of what parts of Africa face when they outstrip their water resources. As I watched the TV reports of our Prairie drought I could not believe that we

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† Presented at the symposium, "Future Changes and Challenges to Canadian Water Resources," University of Windsor, 6 June, 1988.

have allowed this farm crisis to develop despite a clear historical record of drought warnings dating back to the 1850s.

The southern Prairies are basically semi-desert, part of the infamous Palliser Triangle. This is a zone of low rainfall and hot, dry summers that the explorer Captain John Palliser called "an extension of the Great American Desert." This is in an area where there are water shortages during normal years and where more than a dozen Prairie rivers face periodic rationing. When I talked to farmers on the Prairies in 1985, during one of the recent droughts, some of them told me that under dryland conditions one should not count on a crop in one year out of three. And yet we have created and subsidized a western farm economy that defies the realities of nature by demanding high production year after year.

Water shortages are not unique to the Prairies. We have water scarcity in the Okanagan Valley and even in such apparently water-rich areas as Southern Ontario. Too many people settle in the same area demanding ever increasing amounts of water and polluting what is there.

When this land was first seen by European explorers, one could dip a cup in any lake or river and drink the water with perfect safety. If you tried that now in any settled areas it would be an open invitation to a whole shopping list of diseases. With our pollution we have created modern versions of the mythical River Styx, whose poisonous waters separated the living from the dead. Canadians living downstream from the St. Clair and Niagara rivers have refused to drink the water and as a result the provincial and local governments have been forced to spend millions of dollars to pipe in less polluted water from upstream.

Fear of pollution is driving Canadians to buy millions of dollars of bottled water and home water filters a year. For most of this century we have had to pour chlorine, itself a very hazardous substance, into our drinking water by the tonne to avoid infecting ourselves with our own sewage. And this is a characteristic of our environmental policies. It is "react and cure" rather than "anticipate and prevent." As a result we are sliding farther and farther behind. For all our big sewage treatment plants most of our city waterfronts are so polluted that most of the time we do not even dare swim there.

The Great Lakes have become known internationally as a chemical hotspot. In 1985 the Royal Society of Canada and the U.S. National Research Council described the Great Lakes as one of the most toxic areas in North America. Researchers from both countries said people living around the lakes are probably exposed to more toxic chemicals than any other population on the continent.

Furthermore, we are radically changing our aquatic ecosystems. We have destroyed some aquatic life forms and introduced other, often less desirable creatures such as the sea lamprey, sometimes called the vampire of the deep. Scientists are reporting growing signs of an epidemic of fish cancers, particularly in the Great Lakes. Downstream, in the St. Lawrence River, the world's southernmost colony of beluga whales is dying off. The whales are

washing up on shore, laden with toxic chemicals, some of them apparently from as far away as Lake Ontario. The whales are so laden with chemicals that they qualify as hazardous waste.

We have traditionally thought of water pollution as something which flows from sewers or is spilled by boats or factories. But airborne pollution is turning into a bigger threat than anyone realized just a few years ago. Acid rain is probably the first pollutant that comes to mind, but it is just the tip of the iceberg. We are now measuring levels of chemical fallout around the world which indicate that no watercourse can remain pristine and uncontaminated.

And the rapidly approaching "greenhouse effect" will likely turn out to have the greatest impact on our water of any human-induced change, as Marie Sanderson and the Great Lakes Institute group have pointed out. Of course the greenhouse effect will not just disrupt the water balance of the Great Lakes but will have effects across Canada and around the planet.

If the predictions about less water in our prairies are accurate then we are obviously heading into serious trouble based on this year's experience. On a global scale they indicate that this kind of disruption will occur in one country after another. Some presently rich farm areas will turn into deserts. Other areas which are now too dry, will get more rain. The implications are serious for drinking water supplies, food production, population movement, and finally military reaction, to protect the *status quo*.

One particular issue in Canada will be increased pressure for something that a lot of people are concerned about—water diversions. There is the likelihood of more short-range diversions within the country. For example, there will probably be increasing pressure for diversions from northern to southern Alberta, which would lead to even more conflict. We already have a situation in which the Alberta government has been taken to court in an effort to prevent it from building the Oldman Dam to increase water for irrigation. And there may be pressures for diversions within Saskatchewan. Certainly we will see pressure for regional water diversions, at least in the form of more giant pipes, in such areas as Southern Ontario. There is periodically talk of a pipeline from Georgian Bay to the Toronto area.

In the United States we shall see a continuing battle for water between the dry southern and the water-rich northern half of California. This struggle will be repeated in various parts of and between other states. Will it spill over to include Canada? For years there have been schemes proposed to divert water from the Great Lakes or the Yukon area to the dry U.S. areas. Realization of such mega-projects depends on whether people can raise the billions of dollars and the political will and public support needed to mount them. Almost certainly the drying up of the U.S. grain belt by the greenhouse effect will result in calls for water exports from Canada. I note with interest a statement in 1984 by the U.S. Council of Foreign Relations: "Fresh water, long considered inexhaustible and hence a free good, now begins to appear as perhaps the major long-range resource issue on the continent." It warned that "rising demand, especially by

Americans, can cause problems of unprecedented seriousness since water is clearly the most precious of all continental resources." And I underline the word *continental*.

There are alternatives to water diversions. People in the United States could dramatically reduce the amount of water they use for farm irrigation. And they could let more land go back to dryland farming and grazing, and so defer and possibly avoid the water shortages that are already appearing in the United States.

There is another potential for conflict between the two countries over water, that of uncontrolled consumption from the Great Lakes. Both nations take up large amounts of fresh water and do not return it to the lakes. As demand increases and the supply diminishes, thanks to the greenhouse effect, the drop in lake levels could worsen, resulting in greater social and economic costs. In 1985 the International Joint Commission, a body that advises Canada and the United States on boundary water issues, released a warning that there is "a potential for dispute and conflict" between the two countries over the right to Great Lakes water. The group said water issues are so important that the two nations should take special precautions to avoid letting consumption rise to the point where it would reduce water levels.

What are the driving forces that will affect our water future? Two of the most important are population growth and the voracious desire by almost everyone for a greater share of the planet's resources.

The rate of population growth is truly staggering. When I was born forty-five years ago the world's population was 2.3 billion people. Now it is over 5 billion. It has doubled in my relatively short lifetime. It is growing at the rate of about 80 million people a year—three times the population of Canada. And it will keep growing. By the end of the century it will be 6 billion, 20 years later it will be 8 billion, and by the middle of the next century it is likely to be 10 billion. According to last year's report of the World Commission on Environment and Development there will be a five- to ten-fold increase in world industrial output by the time the population stabilizes.

What does this imply for our waters, for example the Great Lakes? There are now 37 million people in the Great Lakes basin; this population is predicted to double in less than 40 years. Such an increase will create strong economic pressures not only to raise industrial output for that population but for export to growing world markets.

Clearly the economic demands posed by the coming population increases here and around the world are not sustainable if we continue to do business in the same old way. If we are going to get at the root causes of our water problems we have to look for common threads. What do dried up Prairie farms, PCBs in the Niagara River, and acid lakes across eastern Canada have in common?

We are beginning to realize that they are not just aberrations but the results of what we have long considered normal business policies. Our environmental situation will not improve until we change business practices, governmental

decision-making, and common behaviour. Given the time it takes to make such changes, the prognosis for at least the next few years is grim. Our water situation will certainly get worse before it can get better.

Pollution damage will increase and the demand for fresh water is growing far faster than are water conservation plans. Even our underground water reserves are at risk. Several years ago an Environment Canada study warned that: "We are in great danger of contaminating our ground water irreversibly with carcinogens and other toxic pollutants." Across the land thousands of landfills will continue to leak into our waters until the dumps are either contained or finish discharging their toxins. Along the Niagara River just four of the big U.S. chemical dumps, including Love Canal, hold enough toxic waste to fill a line of 10,000 tanker trucks that would stretch from Niagara Falls to Toronto. This point was driven home in a report released in May 1988 by Ontario's environment ministry, which said that levels of several toxic chemicals have increased on the U.S. side of the Niagara River over the last couple of years.

We are winning battles against pollution and losing wars. Some programs have reduced pollution while others have actually helped increase it. Some chemicals have been regulated and are being brought under control while others seem to elude control.

According to the federal water inquiry, the Pearse Commission, the Canadian public believes that government water policies are disorderly, fragmented and weak. I think the commission was being kind. What we have is a mishmash of pollution and water use rules which are supposed to protect our water resources. We do not even have a very clear idea about what is happening to our waters because we lack a true accounting system to monitor what we are doing now. We have a lot of facts but too little analysis. We need a truly national reporting system on the state of the environment that would draw together the knowledge of federal, provincial and municipal governments along with that of other experts from business, environment groups, and academe.

With better knowledge about what we are doing we would have a better chance of forging a national water plan. Now we only have pieces in the form of programs here and projects there. For example, we have the Great Lakes Water Quality Agreements, which are aimed at cleaning up the Great Lakes. And Ontario has the Municipal-Industrial Strategy for Abatement, while Quebec has designated cleaning up the St. Lawrence as a major priority. Across the east there is an acid rain reduction program, and across the country, but particularly in the west, there is an ambitious program to save wetlands, called the North American Waterfowl Management Program.

There are beginnings but so far they have few teeth and barely hint at the idea of making people pay a realistic amount for the water they use and they waste. Who will knit these elements together into a coherent national water policy? Where is the sense of vision needed for the future of our waters? Where is the manifesto guaranteeing clean, fresh water for our future?

The lack of driving purpose causes our policies for water and for the rest of

the environment to move in fits and starts. And the longer we wait the harder the job gets. Every day increasing demand presses in on a constant resource. For example, take the increasing demand for energy. In our search for more electricity we will be faced with difficult tradeoffs. Hydro-power is described as clean. But it dams wild rivers and in some areas leads to more mercury being released from vegetation into the flooded areas, making fish unsafe to eat. There will be increasing conflicts as one province after another moves to dam more of its remaining free-flowing rivers. Nuclear plants demand large amounts of cooling water and the nuclear fuel cycle releases radioactive substances. Public opinion does not favour more nuclear power. Coal-burning power plants add to acid rain and the greenhouse effect along with other forms of air pollution.

Governments and industry are faced with more and more expensive clean-ups as we try to repair the damage of past practices. The estimated cost to clean up just one PCB dump near Smithville on the Niagara escarpment is \$48 million. It will cost about the same amount to remove the Sydney tar ponds, a source of water pollution in Cape Breton. I calculate that it has cost Canada and the United States over \$16 billion in the last two decades to reduce sewage discharges to the Great Lakes alone and the job is not over yet. Within Canada there are estimates that we need to spend close to \$5 billion to rehabilitate our aging water and sewer systems before they fall apart and cause us even more expensive problems. I heard recently that the bill could be as high as \$15 billion.

If we are to find solutions for our water problems it must be done in the context of total environmental protection. To draw from the report of the World Commission on Environment and Development known as the Brundtland Report, we must start living within our ecological means. We are reaching a crucial period in the industrial revolution, which started only two centuries ago—a mere blip in the lifespan of the human race. The industrial revolution must be tamed before its side effects become untenable. To do so we must modify our economic system toward forms of business that are sustainable over the long term. Major changes are necessary in such key economic sectors as farming, forestry, mining and smelting, chemical and energy production. And these changes must come rapidly, and include more conservation of limited resources, more recycling of valuable materials, and more use of renewable energy.

One of the biggest questions is who will take responsibility for such change. Last fall Canada's National Task Force on Environment and Economy, a group including environment ministers, business, and environmental leaders, issued its own recommendations. It put the major responsibility in the lap of Canada's first ministers. It suggested that they, and society at large, can be helped through the difficult transition ahead by special advisory groups, which they said should be called round tables on environment and economy. At the time of writing, Quebec is close to announcing a round table; Manitoba is likely to

create such a group, as is Ontario, while Nova Scotia and British Columbia have indicated they will probably create such bodies. Ottawa is likely to create the beginnings of a national group that will include members from the provinces and territories.¹

Returning to Canada's water future, I conclude that we are water rich but policy poor. Our river flow is 9% of the world's water supply. We have one-seventh of the world's freshwater lakes, far more per capita than other nation in the world. And yet we have stumbled into one water crisis after another.

Public opinion polls say people are aware that we have serious environmental problems and want change. Politicians are starting to take environmental issues more seriously and to look for innovative ideas. Consequently a great deal of responsibility rests on groups like the Royal Society, the Science Council, and other major bodies in Canada, not only to provide a coherent synthesis of our scientific understanding of the state of our environment, based upon scientific information and numbers such as the levels of contaminants in parts per billion, but also to provide ideas for change that will stop our pollution.

¹ Round Tables now exist in N.S., N.B., Que., Ont., and Man. A National Round Table chairman is appointed, members to follow soon.

ACADÉMIE I

**Académie des lettres
et des sciences humaines**

**COLLOQUE :
LA DYNAMIQUE URBAINE**

Envahissement et croissance incontrôlables des Métropoles latino-américaines[†]

I NOUVELLE DIMENSION DE L'URBANISME

DANS LE CADRE de l'accélération amorcée du processus historique traditionnel de croissance urbaine, l'on perçoit, parallèlement, une destruction rapide des Hypothèses et des Explications préalables; cependant les concepts scientifiques, inspirés des réalités du passé, persistent à s'imposer comme si les phénomènes de mutations récentes n'intervenaient pas.

La problématique de cette situation étant complexe, il va de soi que le concept même d'urbanisation s'inscrive dans cet ordre de réalités pressenties, d'une manière d'autant plus frappante qu'il fait partie d'un patrimoine quotidien. Il nourrit aujourd'hui un «chapelet de vérités populaires» s'appuyant sur des conceptions dépassées.

La plupart des pays latino-américains en voie de développement se distinguent des pays dits développés, en particulier par le fait que l'impact des modernisations y est le plus souvent ponctué; celles-ci ayant tendance à se manifester en des points bien déterminés, notamment dans les grandes villes, tout en rencontrant une inertie considérable à leur diffusion. Bien sûr, les modernisations récentes, dont on peut fixer le début à partir des années cinquante, se caractérisent par leur capacité nouvelle de bouleversement.

L'un des principaux problèmes de fond s'applique à la pénétration de l'économie commerciale, c'est-à-dire à l'extension d'un système généralisé d'échanges dans des aires géographiques sous-développées qui favorisent la naissance d'une organisation régionale ou contribueraient à la renforcer. La commercialisation pourrait donc déterminer positivement une structuration de l'espace. Sans échanges, donc sans flux d'aucune sorte, «l'Espace géogra-

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[†] Présenté au colloque, "La dynamique urbaine," University of Windsor, 7 juin, 1988.

pique » se retrouverait sans structure et pourrait être qualifié d'indifférencié. Le commerce crée inévitablement la base elle-même de la structuration régionale, mais peut-il lui permettre d'atteindre un niveau de perfectionnement qui réponde, en matière d'espace, aux critères optimaux de rationalité ? La régionalisation serait-elle alors assurée par le développement de la seule économie des échanges ?

On peut sans doute discuter sur le rôle de la ville vis-à-vis de son « umland » ou sur la contribution, positive ou négative, qu'elle représente par rapport à la croissance économique du pays. Toutefois, si l'on se réfère essentiellement à la notion d'espace national ou régional, c'est-à-dire à différentes échelles, les villes apparaissent, soit habilitées à présider un réseau de relations plus ou moins étendu ou complexe, soit inaptes à maîtriser l'environnement spatial périphérique ; ce qui implique des conséquences dans le domaine de l'étude de la croissance économique et de la distribution spatiale des activités des hommes. (Figure 1)

2 ARMATURE URBAINE ET DIMENSION DE LA VILLE

Les rapports ville-campagne se sont considérablement modifiés depuis un quart de siècle, au point où le concept d'espace se trouve de plus en plus conditionné par l'accentuation de la polarisation urbaine.

Dans l'ensemble des pays latino-américains, on décèle une nouvelle dimension de l'urbanisme consécutive à un énorme accroissement démographique, alors que le milieu dans lequel doit s'insérer une proportion importante de la population devient essentiellement urbain plutôt que rural. C'est donc dire qu'en Amérique latine, le continent le plus urbanisé du Tiers monde, on observe que la proportion urbaine de la population atteint déjà des pourcentages élevés, soit près de 70% au Brésil, en Colombie, au Mexique, au Pérou et au Vénézuéla, ainsi qu'un peu plus de 80% au Chili et en Argentine. Cependant, bien que chacune des Grandes Villes possède des caractéristiques propres, l'on observe une certaine convergence entre cette croissance urbaine et l'accroissement du revenu chez les mieux nantis qui s'y regroupent par îlots ou par quartiers. (Figure 2)

Dans ces pays davantage urbanisés, sans toutefois devenir riches, ce processus, à la fois massif et anarchique d'expansion des Métropoles, est loin d'indiquer un progrès réel et s'inscrit bien souvent à titre de handicap sérieux au développement sous toutes ses formes. L'encombrement des villes dépourvues de toute structure d'accueil en dehors des zones d'habitat spontané qui, quoiqu'on en dise, constituent une sorte de havre pour les déracinés ruraux, favorise la prolifération d'un sous-prolétariat marginal et la multiplication de phénomènes d'une culture populaire associée à la pauvreté.

Initialement, la position périphérique des villes tendait à renforcer les déséquilibres géographiques dus à leur implantation initiale. Toutefois, l'intériorisation des armatures urbaines, tant au Mexique qu'en Colombie,

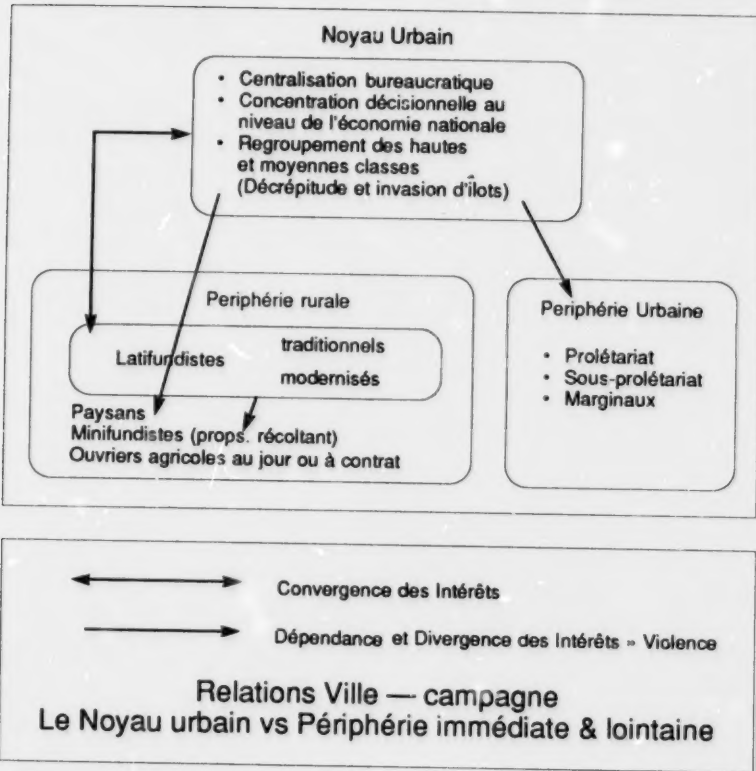


FIGURE 1

avait permis d'établir et de maintenir un facteur d'équilibre pour leur développement. *Grosso modo*, la concentration de la population dans les capitales et dans un nombre réduit de grandes agglomérations, concentrées sur une portion restreinte du territoire, s'oppose à la formation d'un réseau urbain intermédiaire, investi d'agglomérations de tailles moyennes ou petites ; ce qui contribue à accentuer l'écart entre les régions de croissance et les régions déprimées, entre régions fortes et régions faibles.

En conséquence, les déséquilibres les plus remarquables sont ceux qui résultent de la primauté des capitales. La prédominance des capitales peut être considérée comme un facteur de déséquilibre à l'échelle de l'armature, car la hiérarchie urbaine n'atteint un état d'équilibre que lorsque les grandes agglomérations peuvent s'appuyer sur un nombre plus grand de villes de niveaux inférieurs. Cette prédominance des capitales est exceptionnellement évidente en ce qui concerne San Jose, Asunción, Lima et Montevideo. Ces phénomènes d'hyper-urbanisation peuvent également être issus du déséquilibre

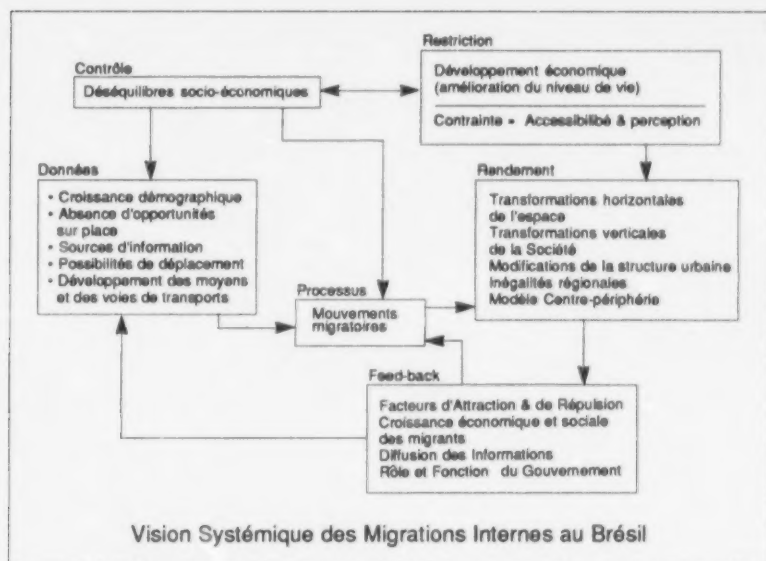


FIGURE 2

dans les fonctions, lorsqu'on retrouve au second niveau des « Métropoles d'équilibre » et des « Pôles de Croissance. »

Dans les zones où les communications sont plus faciles, des « Villes Nouvelles » surgissent fréquemment autour des plus grandes agglomérations. Mais elles sont le plus souvent « satellisées » et « incorporées », en quelque sorte, à un tissu urbain continu. D'autre part, la structure des activités dominantes, la stratification sociale et le pouvoir de décision dans la vie politique et économique de la Nation ordonnent les véritables fonctions des villes. Les très grandes villes et capitales attirent des équipements rares ou sophistiqués, l'implantation des foyers de décisions et récupèrent, sans effort, les fonctions exercées par les villes de deuxième niveau dont l'autonomie s'affaiblit. En outre, la « Primauté » peut s'appuyer sur la centralisation des circuits, financiers et bancaires, qui fournissent les médias d'information et la disponibilité de l'information et se situent à la source même des pouvoirs de décisions.

Au niveau de « l'Armature Urbaine, » on peut distinguer *Trois Catégories de Déséquilibres* :

Des phénomènes de « Primauté Déguisée » dans les pays qui disposent déjà d'une armature à peu près complète : Brésil, Colombie et Mexique.

Des phénomènes de « Primauté Apparente » dans les pays dont l'armature urbaine est incomplète et où il est possible d'observer la perte de vitesse des

villes intermédiaires, notamment dans les pays andins, où la stagnation des petites villes persiste, comme c'est également le cas en Argentine.

Des phénomènes de « Primauté Absolue » où la capitale écrase complètement les autres villes, tel qu'on peut le constater, de façon très nette, en Uruguay, au Paraguay, au Costa Rica et, jusqu'à un certain point, au Pérou et au Chili.

3 LA NOTION DE DENSITÉ DANS UN MILIEU URBAIN EN QUÊTE D'UN OPTIMUM, TOUT EN ÉVITANT LE MINIMUM

Toutes les grandes agglomérations latino-américaines sont investies de zones plus ou moins étendues, plus ou moins sporadiques, si l'on tient compte des contraintes des sites et des aires d'habitat précaire. « L'inquiétude urbaine » qu'on y décèle et qui est plus récente en Afrique qu'en Amérique Latine suscite, et continuera de le faire irréversiblement, des crises politiques auxquelles il sera difficile de pallier, tout en tenant compte de la déficience des équipements et des services dont l'on dispose, même dans les Métropoles.

En observant une baisse régulière des taux de Naissance et de Mortalité dans l'ensemble de l'Amérique latine au cours de la période 1960-80, on y décelait une croissance absolue de 145 Millions de personnes ; en vingt ans la population passait de 203 à 353 Millions. Une base démographique aussi élargie exerce des pressions considérables sur des régimes économiques assez rigides qui ont relativement peu d'influence sur le rythme de croissance anticipé pour la période actuelle 1980-2000. Les problèmes se multiplient à l'échelle régionale et prennent plus d'ampleur dans les Métropoles qui subissent les conséquences néfastes de mouvements migratoires incontrôlables en provenance de régions, soit éloignées, soit immédiates.

Si les rapports « ville-campagne » en Amérique latine relevant exceptionnellement de relations « modernes », l'accélération des processus d'urbanisation, dans certains pays privilégiés, entraîne, néanmoins, une objectivation du besoin d'espace et une évidente compétition pour le sol. Entre marché urbain et espace agro-pastoral, on constate des relations dites régionales et extra-régionales qui interviennent sous l'influence de Deux Circuits : un « circuit traditionnel » qui est davantage relié aux secteurs autonomes de l'économie urbaine et rurale, et un « circuit moderne » plutôt rattaché à l'économie mondiale ou, dans une certaine mesure, au fonctionnement du réseau urbain mondial.

Ce double circuit a donc eu plus de chances d'exister dans tous les pays latino-américains qui subissent un important exode rural et, en conséquence, une augmentation remarquable de leur population urbaine. Ainsi, denrées et vivres sont commercialisés par des flux différents dans le cadre du circuit traditionnel, puisque les uns sont destinés presque exclusivement à l'exportation et les autres, à la consommation locale du milieu rural. Cependant, la situation a changé, quand s'est développé un important marché des vivres

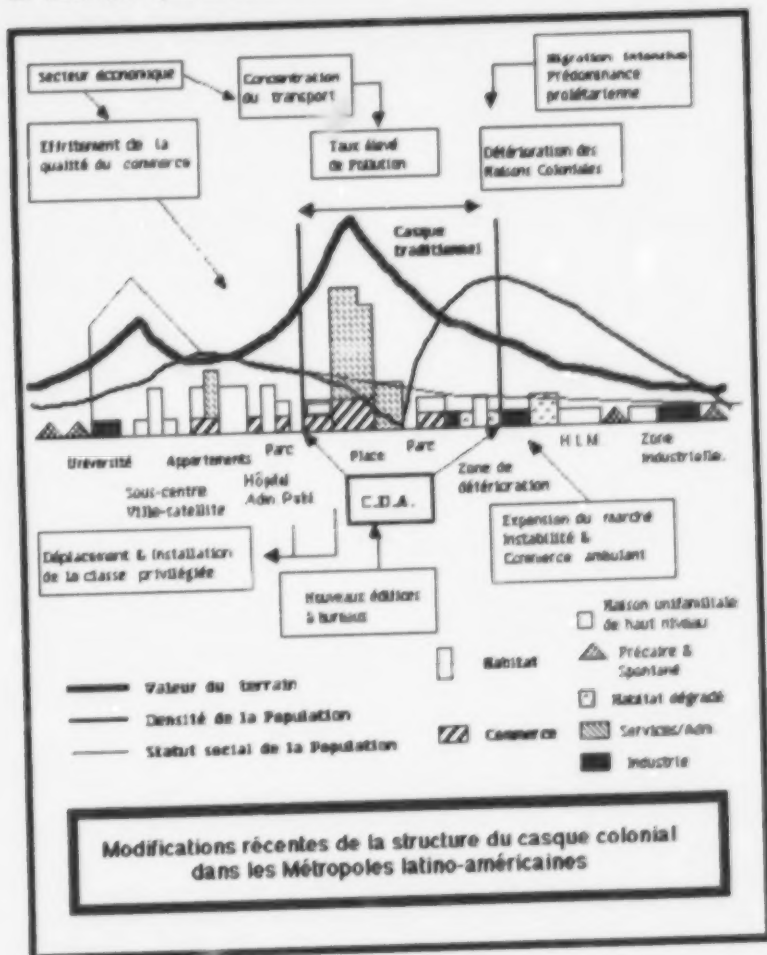


FIGURE 3

traditionnels (céréales) pour les villes, mais aussi quand celles-ci sont devenues consommatrices de nouveaux « vivres de luxe » (viande fraîche, fruits et légumes), lesquels se sont transformés irréversiblement en objets d'un commerce international. L'« importation » devenait nécessaire et la « spécialisation » prenait de l'ampleur.

Le tout se traduisait par une expansion urbaine considérable et la crise qui en résulte dépend du transfert de la force de travail de la campagne à la ville, alors que le taux de chômage augmente et que le sous-emploi, « formel ou informel », persiste, atteignant de 30 à 40% dans quelques pays. L'isolement

traditionnel des ruraux s'estompe. Une exploitation commerciale technifiée requiert moins de main-d'oeuvre et se substitue à une agriculture de subsistance.

Dans ce contexte, la notion de *Densité* s'atténue dans les campagnes mais s'accroît dans la majorité des villes. Certes, son interprétation doit demeurer en rapport avec des habitudes propres à la culture, aux avantages ou désavantages bio-physiques et climatiques du milieu ambiant, des disponibilités des surfaces planes ou accidentées, ainsi que différents modes de perception de l'espace et de sa lisibilité. Voilà pourquoi doit s'inscrire une distinction entre *Densité nette* (rapport population / surface de plancher par îlot ou parcelle, incluant des surfaces utilitaires ; rues, places, cours et jardins) et *Densité brute* (rapport population / surface de plancher par quartiers englobant des espaces non bâtis discontinus). Figure 3

En Amérique latine, toutefois, il est préférable de s'en tenir à cette *Notion de Densité Brute* qui démarque les espaces urbains par rapport aux marges rurales, alors qu'un certain nombre de critères risquent d'être arbitraires. Cependant, son interprétation risque également d'être trompeuse en ce qui concerne les aires récréatives ainsi que les surfaces de plancher occupées par des commerces et des services, et ce, sans insister sur les cas multiples de surpeuplement critique d'édifices à logements dans des zones où de vastes terrains vacants l'affaiblissent. A mesure qu'évoluent les Grandes Métropoles, plus la fixation des densités d'occupation devient complexe et différenciée à l'échelle des îlots, des Quartiers et des Unités de Voisinage. D'autres contraintes exercées par la valeur foncière s'y ajoutent, obligeant à choisir entre deux maux : *Surcharge d'occupation et Ségrégation sociale*.

C'est donc dire que depuis 1950, l'urbanisation est devenue, par elle-même, d'une importance vitale, dans les rapports de l'homme avec la biosphère, car le milieu naturel urbain actuel exige beaucoup plus d'énergie et de matières par habitant pour répondre aux besoins humains essentiels que les villes et villages de l'ère pré-industrielle. Dans ce contexte, une perception écologique de l'espace urbain devrait être retenue, malgré les embûches, puisqu'il existe certainement une corrélation importante, quoique fort mal perçue, entre les modes de consommation d'énergie et de circulation des produits dans les villes, ainsi que l'état de santé physique et même mentale de la population urbaine.

4 SOUS-CULTURE, DÉCALAGES SPATIAUX ET PLANIFICATION

Dans l'ensemble de l'espace latino-américain, sous-culture et pauvreté n'expriment pas simplement une question de privation ou de désorganisation. Au départ, les styles de vie transcendent les frontières nationales et les différences régionales, urbaines et rurales à l'intérieur des Nations, que ce soit au Mexique, au Pérou ou au Brésil.

Aujourd'hui même, la répartition des populations appauvries dans les milieux ruraux et urbains constitue le problème le plus sérieux. D'ailleurs, le

sous-emploi chronique et cyclique en milieu rural à saison sèche prolongée, sans possibilité d'irrigation, sans tradition d'agriculture irriguée ou encore en zone de monoculture, a toujours provoqué des afflux urbains difficiles à contrer. On assiste ainsi à une transposition en milieu urbain, sur des surfaces restreintes (ilots, lotissements abandonnés et quartiers) occupées par différents types d'habitat précaire, une foule de problèmes dilués au sein d'espaces ruraux parfois fort étendus. Rappelons, cependant, que les effets de répulsion exercés par un milieu rural en voie de paupérisation n'agissent pas toujours de la même façon.

Les migrations rurales et interurbaines s'appliquent à partir d'une théorie de la convergence s'appuyant sur une offre d'emplois à titre de « facteur de production mobile ». Le contexte d'un environnement morcelé dans le cadre d'une véritable culture de pauvreté correspond à un : « crash economy » avec travail salarié (formel) et production pour le profit, un taux constamment élevé de chômage et de sous-emploi, ainsi que des salaires très bas pour le travail non-qualifié (informel).

Un véritable mécanisme d'acceptation constitue donc ce « facteur de production mobile » assurant la convergence en direction d'une véritable « zone-refuge » apte à pouvoir fournir, en principe, prestations et travail. Cette théorie ayant un sens de l'équilibre est valable si les conditions suivantes sont déjà en place :

- 1 l'absence de barrières sociales ou économiques ;
- 2 des migrants nombreux et homogènes, compte tenu de leurs qualifications ;
- 3 les migrants sont au courant des opportunités d'emploi ;
- 4 les migrants sont motivés par leur désir de maximiser leurs revenus ;
- 5 les migrants sont motivés par leur désir d'améliorer leur statut social.

C'est donc dire que leur intrusion massive dans des milieux urbains congestionnés et sous-équipés s'accompagne d'une véritable transposition des retards technologiques culturels et sociaux du milieu rural en milieu urbain. Ainsi, le Brésil archaïque ne disparaît pas, mais se répartit entre les zones rurales et les quartiers urbains. Le « nouveau dualisme brésilien » élargit le fossé économique et culturel entre participants et exclus. C'est pourquoi l'importance du marginalisme urbain constitue un véritable constat d'échec de la Métropole en tant que « Pôle de Développement Régional, » en même temps que source potentielle au blocage du « Miracle économique. »

Parallèlement, la classe dominante affirme un ensemble de valeurs qui donne la prépondérance à la propriété, insiste sur la possibilité d'une mobilité qui va dans le sens ascendant de l'échelle sociale et explique une position économique inférieure comme le résultat d'une infériorité et d'une insuffisance personnelle.

Quand ces conditions prévalent, le mode de vie qui se développe parmi certains de ces pauvres correspond à une sous-culture de l'ordre social occidental, soit une adaptation et une réaction des familles paupérisées à une position marginale dans une société stratifiée, en classes hautement indivi-

dualisées, et essentiellement capitalistes. Dès son apparition en tant que culture, la pauvreté tend à se poursuivre. A partir de six ou sept ans d'âge, nombreux sont les enfants qui ont pratiquement assimilé les attitudes et les valeurs fondamentales de leur sous-culture, en vivant dans des secteurs taudifiés, où les familles sont souvent abandonnées par le père. Ultérieurement, ils ne parviennent pas à pouvoir tirer partie, psychologiquement, des conditions nouvelles ou des occasions d'améliorer leur sort au cours de leur existence.

Graduellement, la ville a de moins en moins besoin des campagnes, alors que celles-ci en dépendent de plus en plus. La relation principale de domination n'est donc plus celle de la subsistance et du profit agricole, mais bien plutôt celle de la consommation, de l'emploi, de l'espace et aussi de la qualité écologique de l'environnement ; cette dernière notion, encore mal perçue par les résidents, révèle de façon symptomatique deux situations différentes, mais également dramatiques par le poids des contraintes qu'elles leur imposent.

D'une façon générale, c'est une stratégie visant à promouvoir des Pôles de Croissance externes ou périphériques qui prévaut en Amérique latine. La planification en tant que telle s'exprime dans le cadre de divers schémas sectoriaux, régionaux, urbains et ruraux, autant qu'en fonction de leurs objectifs spécifiques et de leurs niveaux d'implantation.

Puisque les buts qui ont prévalu dans la majorité des pays latino-américains, lorsque les systèmes de planification furent introduits avec différents degrés de complexité, notamment en ce qui concerne les Aires Métropolitaines, plus incontrôlables et plus ingouvernables administrativement, ces systèmes ont affiché leurs résultats obtenus dans des champs d'action très limités de l'économie et ont aidé plus spécifiquement les groupes qui ont décidé, de façon directe ou indirecte, à introduire de telles instructions. (Figure 4)

En fait, c'est à partir de l'influence des groupes de pouvoir et des « grands hommes d'affaires » que les « opérations de planification » n'ont pas été des cas péremptoires d'échecs. Au contraire, la distribution des revenus a souligné une concentration plus grande entre les mains du groupe le plus riche au cours des dernières décennies et on n'enregistre guère de véritables changements dans le système de la propriété. En tenant compte de la grande majorité de la population, les résultats du Développement ne se sont pas dispersés, démontrant, une fois de plus, que l'essor capitaliste, la croissance et les affaires sociales ne vont pas ensemble, puisque la tendance en vue de retenir un type de croissance qui n'affectera pas négativement la position des groupes au pouvoir se trouve inhérente à l'ensemble du système.

5 PRATIQUES FONCIÈRES ET PERSPECTIVES DE REVITALISATION DE « CASQUES URBAINS » : LOGEMENT, DÉLOGEMENT ET RELOGEMENT

Les fonctions du sol et du logement urbain variant considérablement d'un pays à l'autre en Amérique latine, la majorité des grands ensembles affichent une relative homogénéité, malgré une émergence progressive et agressive de la

Position ou Fonction

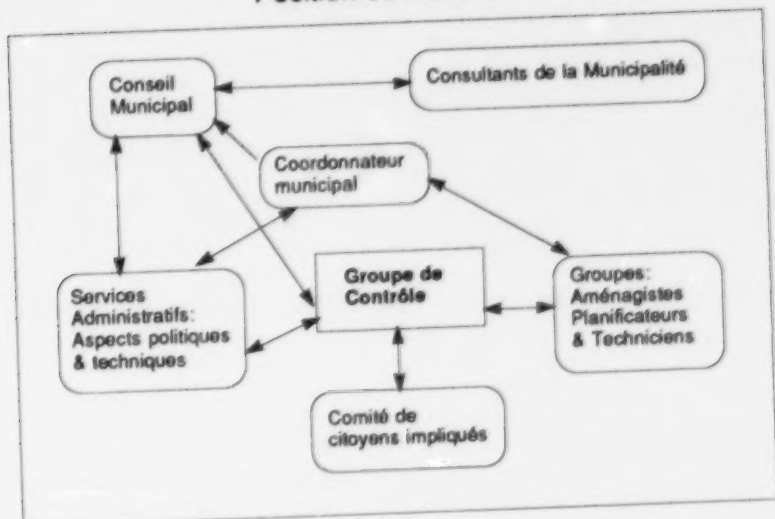


FIGURE 4

question foncière. Mais les facteurs de différenciation y étant nombreux, suite à l'évolution rapide des fonctions, toute généralisation hâtive demeure difficile. A mesure que s'accélère un irréversible processus de privatisation du sol urbain, aménagistes et gestionnaires professionnels procèdent à un accaparement du sol, tant urbain que péri-urbain. Les propriétés foncières traditionnelles des franges rurales adjacentes disparaissent spontanément sous l'impact d'un mouvement de concentration des terres par un nombre limité d'agents et par un taux d'accroissement soutenu de prix du sol ; ce qui exclut l'accès légal au sol urbain d'un pourcentage croissant de la population de classe moyenne.

L'accès au sol et le logement restent donc des objectifs à définir, un cadre et des hypothèses à déterminer dans la grande majorité des pays concernés. Malheureusement, plusieurs objectifs nationaux en matière de production de logements sont à la baisse, notamment dans le cas des bas revenus et ce, à l'avantage des groupes supérieurs, via une ségrégation spatiale accrue et un encouragement à l'étalement urbain. Des filières de gestion, de contrôle par l'État et à caractère populaire se superposent sans se conjuguer harmonieusement, puisqu'elles demeurent sous la gouverne des agents qui interviennent lors de chacune des phases du processus de production foncière et immobilière par voie d'appropriation et d'expropriation.

Aujourd'hui, on constate avec étonnement qu'il y a peu de recherches et de programmes élaborés sur les changements de structure aussi exceptionnels que

disparates dont ont souffert les « casques urbains pré-industriels », malgré l'importance des aspects urbanistiques, architectoniques, écologiques et socio-économiques concernés. L'influence de l'industrialisation qui s'y est infiltrée tardivement demeure parasitaire, malgré les changements de style architectural, des transformations fonctionnelles et des mutations de caractère économique qui obligeaient des déplacements en quête de lieux stratégiquement rentables.

En analysant les phases qui se sont succédé d'hier à aujourd'hui, on peut observer que le déséquilibre s'est accentué entre le Centre et sa Périphérie. Divers modes d'occupation des aires, découpées en parcelles, se sont graduellement imposés autour de la classique formation du cercle de quartiers divers qui enveloppent la Place Centrale *Plaza Mayor ou Zocalo*. Les maisons désaffectées y foisonnent et de nombreuses propriétés à caractère multi-familial en piteux état *conventillos, vecindades et cortiços* sont récupérées par des groupes d'agents qui les offrent, sous forme de cohabitation par pièces individuelles dans chacun des appartements, à des familles délogées ou sans abris, lesquelles se trouvent relogées dans des conditions de promiscuité et d'hygiène alarmantes dans des immeubles étagés où la densité d'occupation devient catastrophique ; ce qui est malheureusement le cas autour de la « Praça da Sé, » au coeur de *São Paulo, au Brésil, Métropole jumelée à celle de Toronto depuis juin 1987*, suite à la signature d'un protocole d'entente touchant la coopération technique et administrative dans le cadre d'un Programme international financé par l'ACDI.

A fin de ralentir le vieillissement et l'effritement constant de nombreux édifices dans la plupart des îlots à caractère résidentiel, sis à proximité du Centre-ville, une rigoureuse législation s'impose, de façon à pouvoir en contrôler les changements constants et à mettre sur pied un programme intégral de conditions sanitaires normales dans un milieu ambiant affecté par le bruit, la population et l'absence relative d'espaces verts, au profit d'une population sédentaire appauvrie. L'élaboration d'un Modèle Urbain, révisé de façon convenable, devrait s'appuyer sur cinq Facteurs de base déterminants, en y insérant l'importance d'un risque conflictuel à l'état latent :

- 1 élargissement d'un éventail de fonctions économiques offrant davantage de possibilités d'emplois, aux deux niveaux « formel et informel » ;
- 2 amélioration de la circulation et du transport dont l'état, souvent déplorable, dévalorise le milieu ambiant, le bâtiment se trouvant assujéti à la décrépitude ;
- 3 dépendance de la propriété foncière, tributaire des valeurs cadastrales traditionnelles et des fluctuations du marché local ;
- 4 essence et spécificité du patrimoine artistique et de l'évolution historique de son architecture ;
- 5 structure sociale de la population des quartiers urbains en fonction des types d'habitat, de leur disponibilité et de leurs modes d'occupation, souvent demesurés.

La qualité de vie, les problèmes de circulation et d'accessibilité au Centre-ville restent des éléments-clés à cerner et à solutionner le plus rapidement possible; ce qui est loin d'être le cas. Même si les rues ou les artères piétonnières se multiplient dans plusieurs villes, en limitant la circulation des véhicules à des horaires rigoureux. Les lignes souterraines de Métro fournissent des embryons de solution dans les secteurs les plus densément occupés des Grandes Villes. Les autoroutes devraient s'arrêter en bordure du Casque traditionnel lequel, bien circonscrit autour de sa Place Centrale, serait en mesure d'exclure définitivement la circulation des véhicules, du moins celle des camions et des autobus, comme on l'a fait récemment, de la même façon, à Florence en Italie et à Oaxaca au Mexique. D'importants terminus d'autobus ont été récemment transférés du CDA à la périphérie immédiate, notamment à Mexico, à Rio de Janeiro et à São Paulo. Toutefois, un terminus d'autobus, sur-utilisé et coincé entre des voies de circulation débouchant sur le Noyau traditionnel, demeure toujours en place à Caracas alors qu'il est absent à Lima.

Dans le contexte actuel, une préoccupation constante de la qualité de vie, laquelle prend de l'ampleur, permet de conjuguer ou d'associer étroitement des concepts de planification écologique à ceux de la restauration des quartiers centraux. Cependant, les transformations récemment amorcées de nombreuses maisons-appartements surpeuplées en logements d'une seule pièce restent très discutables, puisqu'elles impliquent une ségrégation ethno-socio-culturelle néfaste et incontrôlable dans une série d'îlots formant une « zone grise. » Quelques derniers monuments, édifices, temples sacrés, couvents séculaires, résidences, manoirs anciens et sites historiques du « casque colonial » et des « premières périodes de l'Indépendance » gravitent autour d'une revitalisation radicale, coiffée, en sourdine, d'une approche sociale, d'ambitieux empires immobiliers du Centre des Affaires. Un compromis s'impose pour la conservation du patrimoine dans une morphologie urbaine humanisée en vue de la reconquête souhaitée d'un prestige déchu.

Quoiqu'il en soit, nous constatons que peu de tentatives de logements pour les bas revenus, à l'exception de quelques exemples occasionnels, soit à Bogota, à Mexico, à Rio de Janeiro et surtout à Buenos Aires et à Santiago du Chili, ont permis de dégager des ressources suffisantes pour renouveler ces expériences à une échelle plus large dans les Grandes Villes. En réalité, les programmes d'attribution de terrains ou de logements aux gagne-petits favorisent le plus souvent des tranches de privilégiés de différentes catégories, par le jeu de désignation des attributaires et par le libre fonctionnement du marché après attribution. Dans ces conditions, il s'avère normal que le problème de l'habitat ait atteint des niveaux inquiétants dans les Grandes Métropoles latino-américaines.

Aux Mexique où une famille regroupe en moyenne 5.5 personnes, le système actuel de construction d'habitats de différentes catégories est devenu un luxe insupportable pour la plus grande majorité. L'ampleur du phénomène de « bidonvillisation » qui se poursuit depuis plus de vingt ans à Nezahuat-

Icoyotl, troisième agglomération du Mexique, dont les 4 millions et plus de résidents anciens, plus ou moins récents et nouveaux occupent, à titre de squatter ou « paracaidistas, » comme on les appelle sur place, l'emplacement de l'ancien lac de Texcoco, à proximité de l'Aéroport International du District Fédéral de Mexico où 1 000 personnes y arrivent quotidiennement en provenance des campagnes immédiates ou des régions les plus attardées. Si la marginalité, dite « occupationnelle, » reste un mythe, la moitié des laissés pour compte s'y trouvent en chômage dans cette zone urbaine inclassable, et le même pourcentage d'habitations disparates qui sont passées par toutes les gammes de l'autoconstruction progressive, en fonction de la disponibilité des matériaux traditionnels, ne bénéficient ni d'eau courante ni d'égoût.

Dans le Grand São Paulo, épicentre du capitalisme brésilien, 60% des habitations sont classées comme étant sous la norme minimale, avec un taux d'occupation de plus de deux personnes par pièce. De 250 000 habitants au début du siècle, la population y atteint les 17 millions en 1988. De 200 000 à 400 000 nouveaux immigrants s'y installaient entre 1960 et 1980. Depuis, le nombre d'immigrants annuels oscille autour de 500 000.

Un série de chaos visuels et psychologiques où s'affrontent horizontalité et verticalité dans l'immensité de cette agglomération occupant une surface de 8 105 kms², dont la continuité s'estompe au delà de 2 000 kms², regroupant 37 « Municipios, » expliquent partiellement l'hétérogénéité et l'instabilité du tissu urbain de cette « Hyper-Métropole. » L'énormité de l'écart des niveaux de vie s'ajoute à la complexité de la mosaïque urbaine où se juxtaposent des quartiers différenciés.

Malgré une concentration des secteurs industriels les plus avancés, la superstructure métropolitaine du « Noyau Pauliste » accuse une distribution confuse des aires résidentielles et industrielles, conjointes ou sporadiquement isolées, en plus d'un réseau de transport insuffisant, impliquant 2 lignes de Métro et 960 lignes d'autobus dont la moitié seulement assurent 80% des 12, 5 millions de déplacements quotidiennement effectués. Cette désorganisation explique le flot journalier de la mobilité de la Force Travail et le refoulement d'aires résidentielles très variées en marge de la périphérie immédiate du Noyau Central, plaque tournante de la redistribution des immigrants récents, de souche rurale immédiate, victimes de la concentration foncière de la monoculture sucrière dans le cadre d'un Programme National de « carburant-alcool. » Le monde rural adjacent s'en est trouvé rapidement prolétarisé, entraînant irréversiblement un exode spontané des exclus, une accélération du processus de « favelisation, » ainsi que des risques de catastrophes écologiques résultant de la surexploitation du canevas urbain. S'y ajoute une turbulence centrifuge interne, puisqu'au cours de la dernière décennie, les 2/3 des immigrants ont démanagé d'une sous-région à une autre.

La multiplication de parcelles occupées clandestinement, autour des nouvelles résidences, le long des grands axes, des échangeurs et des terre-pleins centraux, par les « favelados, » dont le nombre est passé de

100 000 en 1970 à plus de 2 millions en 1987, a incité les Autorités du Municipale de São Paulo à amorcer diverses tentatives d'expulsion. Le nettoyage de cette nouvelle « ville sainte » du capitalisme s'inscrivait dans un Programme de Rénovation, de Revitalisation et de Sectorisation du Centre Traditionnel qui entraînait un renchérissement inévitable des coûts de loyers, même dans les « cortiços, » qui y devenaient de véritables ruches de locataires, et des terrains. En même temps, des associations de « favelados » tentaient, tant bien que mal, d'améliorer sur place les conditions de vie et, parallèlement, par « piratage » des services d'eau, de téléphone et d'électricité. Ces tendances n'ont pas empêché l'apparition de nouvelles initiatives financières, s'appuyant sur une base, à la fois spéculative et stratégique, en ajoutant deux nouveaux axes commerciaux, l' « Avenida Paulista » et l' « Avenida Faria Lima » à la « *Praça da Sé*, » créant ainsi une « *Centralité tricéphale*. »

Dans cette dichotomie urbaine aussi rigide, où se conjuguent inopportunément un « pôle décisionnel » et un « enfer urbain », des disparités, des proximités, des oppositions, des interprétations, des contrastes et des complémentarités superposent une ségrégation économique de l'espace et entretiennent une omni-présence des inégalités sociales. Dans le canevas inextricable de cette ville monstrueuse, farçie de cloaques indescritibles, les disparités ne facilitent pas la libération des antagonismes sous-jacents, alors que le « provisoire » et l' « inachevé » persistent.

En somme, si des embryons de solutions ont trop souvent tendance à s'effriter ou ne parviennent à s'imposer qu'avec difficulté dans la plupart des Métropoles, suite à une série de compromis, divers champs d'actions deviennent-ils possibles ou souhaitables malgré tout, en respectant le « statu quo » social local, alors que toute intervention ou action sur le « foncier » ne saurait, en aucun cas, lui être limitée ?

BIBLIOGRAPHIE

Ouvrages, Revues et Articles consultés

- Castells, Manuel, *Questões de Investigação no Brasil*, Ed Presença, Lisboa, 1977.
- *La Question urbaine*, coll. Textes, François Maspero, Paris, 1973.
- Cordeiro, Helena, K., « Sub-setorização da área de transição do CMPS », IV Congresso Brasileiro de Geógrafos, 8 p., São Paulo, 1984.
- Denis, Paul-Yves, « Spatial and Social Pattern in Metropolitan Cities of Latin America: convergence and divergence », CAG Annual Meeting, Nanaïmo, B.C., 12 p., May 84.
- « Reorganization of São Paulos's C.B.D. » CLAG Annual Meeting, Uni. of Ottawa, 10 p., Sept. 84.
- « Percepción Geográfica del espacio urbano : del casco inicial a la mosaica actual », Paisajes Geográficos, No. 21, CEPEIGE, OEA, Quito, Ecuador.
- Damais, J. Ph., « São Paulo 1985 : une « ville » à la poursuite de sa croissance », Ann. Géo., No. 536, 1987, pp. 423-461.

- Durant-Lasserve, Alain, « Pratiques foncières et question du logement dans les villes du Tiers Monde », *La Géographie* - 1984. Images des sciences de l'homme, Supplément au NO. 54, pp. 25-29, Le courrier du CNRS, juillet 1984.
- Geiger, Pedro, « Ensaio sobre a reestruturação do espaço do Brasil », *Revista Geográfica*, No. 105, enero-junio, 87, IPGH, Mexico, pp. 5-23.
- Geraides de Lemo, A.I., « La producción del espacio metropolitano de San Pablo (Brasil) », *Revista geográfica*, No. 101, enero-junio 85, IPGH, Mexico, pp. 45-53.
- Hall, Peter, "Changing Urban Hierarchies in the Development Process: an International Comparison", Working Group in the Great Metropolitan Cities, 1st Seminar, Brasilia-Rio 1982, Publication IBGE, Rio de Janeiro, pp. 145-161, 1983.
- Kleinpenning, J.M.G. & Reitsma, H.A., *The Third World in perspective*, Rowman & Allanheld, 420 p., 1985.
- Harris, Robert, « Le CNUEH—La réussite du travail communautaire », *Développement*, Hiver 1987-1988, ACDI, pp. 45-51, Ottawa.
- Harker, John, « L'explosion urbaine : mythes et réalités » *Développement*, Hiver 1987-1988, ACDI, pp. 21-24, Ottawa.
- Rouquié, Alain, *Amérique latine—Introduction à l'Extrême-Occident*, Seuil, Paris, 439 p., 1987.
- Santos, M., *O Espaço Dividido : Os dois circuitos da economia urbana dos Países Subdesenvolvidos*, Francesco Alves, Rio de Janeiro, 1979.
- Théry, Hervé, *Le Brésil*, Masson, Coll. Géographie, Paris, NY., Mexico, 231 p., 1985.

L'écrivain et la ville[†]

QUAND il m'arrive de passer quelques jours de vacances à la montagne ou au bord de la mer, je n'ai qu'une hâte, retrouver la ville. Et quand je visite une ville pour la première fois, mes pas me conduisent instinctivement à la partie la plus grouillante, parfois la plus sale, mais qui est pour moi la plus réelle de l'endroit. J'aime les grandes villes, New York, Shanghai, Londres. Tout m'y semble possible mais aussi la liberté de me retrancher, de me réfugier dans une retraite voulue.

Est-ce un choix littéraire qui détermine ce désir ou est-ce le désir et son assouvissement qui déterminent ce choix ? Mais d'abord les événements et les circonstances de l'existence. Je suis né dans une ville historique, archaïque et comparée aux grandes métropoles, ce n'était, à l'époque, en réalité, qu'un village retranché. J'ai souffert de l'isolement mais je le situais dans l'environnement de l'époque. Cette ville, Bagdad, était entourée de villages et de désert, du véritable désert. J'ai donc vécu la ville par naissance, même si je me sentais prisonnier de son retranchement. Je l'ai préférée à l'environnement ambiant. Je l'ai choisie et c'est ma première expérience d'un village qui a confirmé ce choix. J'avais découvert que la ville c'est le constant départ et c'est surtout le rêve de départ. Un jour j'ai répondu à l'appel. En compagnie d'un ami j'ai pris un matin le car pour Hilla. Une trentaine de kilomètres de la capitale. Nous étions deux adolescents et nous parcourions les quelques rues de la petite ville. On nous saluait, nous demandait d'où nous venions. Nous étions des étrangers et notre différence nous singularisait. De retour, le jour même, je retrouvais avec soulagement le confort de mon quartier et l'anonymat des autres quartiers. Car, dans la ville, nous étions musulmans, chrétiens et juifs, kurdes et

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arméniens et nous nous retrouvions dans la chaleur et la sécurité de nos quartiers tout en ayant, à notre portée, la multitude des autres quartiers où notre différence, semblable à tant d'autres, ne nous singularisait pas.

Juif, j'étais minoritaire, mais autour de moi, tout le monde l'était. J'avais le loisir de quitter mon quartier, de partir à la découverte d'un monde. Je traversais la rue et je pénétrais dans un univers autre. Je n'étais pas singulier, j'étais différent. Un étranger au quartier dès que je quittais le mien. C'était le cas de tout le monde. La ville, c'était tous les quartiers et si tout le monde est étranger, personne ne l'est. J'ai appris aussi qu'en traversant les frontières invisibles qui délimitaient les quartiers, je me trouvais ailleurs, inconnu. Mon comportement n'était plus soumis au regard sourcilieux et attentif des miens. Mais à ceux d'un autre groupe. On me jugeait comme membre d'une collectivité. Cela m'exonérait comme individu et cela faisait peser sur moi le rôle du représentant d'une communauté. J'ai ainsi commencé à apprendre les limites et la mesure et de ma liberté et de ma responsabilité.

Il m'est arrivé d'aller au-delà du seuil de la maison étrangère. Et c'est alors que je me suis mis à me raconter l'histoire de l'autre. D'abord pour le découvrir et ensuite pour m'expliquer ma découverte. Qui était-ce ? Que sentait-il ? Comment réagissait-il ? Chaque visage cachait une personne et chaque personne avait une histoire à raconter. J'imaginais cette histoire, ne croyant point l'inventer. Je me la racontais et la personne devenait histoire. Et celle-ci me renvoyait à la mienne. Dans ce miroir invisible qui était devenu le visage de l'autre, je voyais le mien et je me suis mis à raconter mon histoire, à me raconter. C'était ma manière de surnager, de vaincre l'ombre, de transformer l'existence en vie.

Plus tard, je me suis dit que le monde existait en dehors de mon invention. Le réduire à une histoire pour l'appréhender, c'était en perdre une ou plusieurs dimensions. Je me promenais au bord du Tigre, je le traversais à la nage et l'une de mes premières nouvelles avait pour personnage, si je puis dire, un banc au bord de l'eau, qui racontait le passage des personnes assises. Plus tard, au Canada, j'ai écrit une nouvelle où mémoire et rêve se mêlaient, ainsi que le Tigre et le Canal Rideau à Ottawa comme personnages. Était-ce une incapacité d'appréhender le monde des objets sans les transformer en personnages afin que l'histoire puisse surgir afin de parvenir à la narration ? Le poète fait l'économie d'une telle transposition. Il n'a recours qu'aux mots et chaque vocable contient son histoire. L'objet et la nature n'ont d'histoire alors qu'incluse dans un mot. On obéit au mot pour le vaincre, sinon le dominer. On s'y soumet pour en faire un outil même si on accepte qu'il ait son autonomie, qu'il ne soit pas reflet ou remplacement mais qu'il ait une existence indépendante de notre volonté. Or, tradition et circonstance ont forgé mon rapport contradictoire avec le mot : suspicion et respect. Et dans les deux cas, distance et éloignement. Suspicion car le mot ne peut être fidèle puisqu'il ne peut être définitif. J'ai changé de langue et j'ai appris à mes dépens que l'expression n'est pas naturelle, ne coule pas de source. Mais respect aussi car, nourri des deux langues sacrées, l'arabe

et l'hébreu, je sais que Dieu a parlé et que sa parole est définitive. Il me reste l'apologie et le commentaire et, aussi, pour contraindre le mot d'aller au-delà de son autonomie : raconter une histoire et le mot devient lui-même histoire. Je contourne ainsi l'interdit sans passer par le fracas de la transgression et je vains ma suspicion en neutralisant le mot, en l'oubliant, en en usant inconsciemment pour raconter.

Je reviens à la ville. J'ai volontairement et comme par instinct traversé les frontières. D'un quartier à l'autre, visages et vêtements se distinguaient et, à force de voir la différence, je percevais ce qui les réunissait, ce qui les unissait. Et la ville surgissait vivante et souveraine par ses quartiers, au-delà de ses quartiers. J'ai connu beaucoup de villes et j'ai toujours cherché à les découvrir entre le ghetto et le désert anonyme. La ville peut être prisonnière de ses quartiers et les transformer en ghettos protecteurs et infranchissables. Mais la ville peut aussi se dissoudre dans le désert de l'anonymat. Chaque individu possède son histoire, mais il ne peut pas la raconter, car il est anonyme, invisible et surtout inaudible. Il est singulier et personne n'est là pour l'écouter, car il ne peut écouter personne. Entre l'enfermement du ghetto et la solitude de l'anonymat, je n'ai de choix que la ville, et c'est là que je revois dans le miroir invisible non pas une cloison, non pas l'unique renvoi de mon propre visage mais le reflet de celui de l'autre. Je m'y reconnais et je m'y retrouve et je lui raconte mon histoire, car elle est au-delà du quartier, au-delà de la frontière, la sienne. Par le quartier et en raison du quartier, la ville aménage la rencontre. Dès lors, l'anonymat n'est plus une condition ni un état, il est un choix, un recours circonscrit dans un moment, une durée. Il est affranchissement voulu. Je quitte le quartier pour y revenir. Le ghetto n'est plus la prison mais le foyer, le lien, le retour. Je parcours la ville avec l'exaltation de la découverte et le secret plaisir de l'anonymat. Découverte dans le visage inconnu non pas d'une singularité, mais d'un lien et dans l'anonymat voulu et momentané, au-delà de la solitude et de l'étrangeté, d'une liberté. Je circule à visage découvert, je suis reconnu comme citoyen de la ville et habitant de mon quartier.

Il m'arrive au cours d'un voyage de visiter un village ou une toute petite ville dont je ne connais pas la langue. Je regarde un enfant sortir de l'école ou jouer dans la rue et je m'imagine à sa place. Je suis pris d'angoisse et je me dis, « Comment fera-t-il pour échapper à cette rue, pour aller en ville, pour découvrir le monde ? » Sans doute, pourrait-il découvrir le monde dans une seule rue. Il pourrait être satisfait de son sort, heureux de vivre parmi les siens. Seraient-ils peu nombreux ? Qui suis-je pour en faire la comptabilité ? Et quelle est l'aune du nombre ? Dix, quinze personnes pourraient constituer un monde plein, riche aux dimensions de l'univers. Et pourtant, mon angoisse n'est point dissipée. Et si j'étais ce jeune garçon, le monde existerait sans que j'en éprouve la présence et encore moins la diversité. Peut-être la curiosité n'est qu'une incapacité de découvrir le monde dans une seule rue et l'homme dans un seul visage. Puisque la ville existe, je ne suis pas seul à être accablé de cette incapacité. Puis je me trouve dans une grande ville et voilà le même garçon

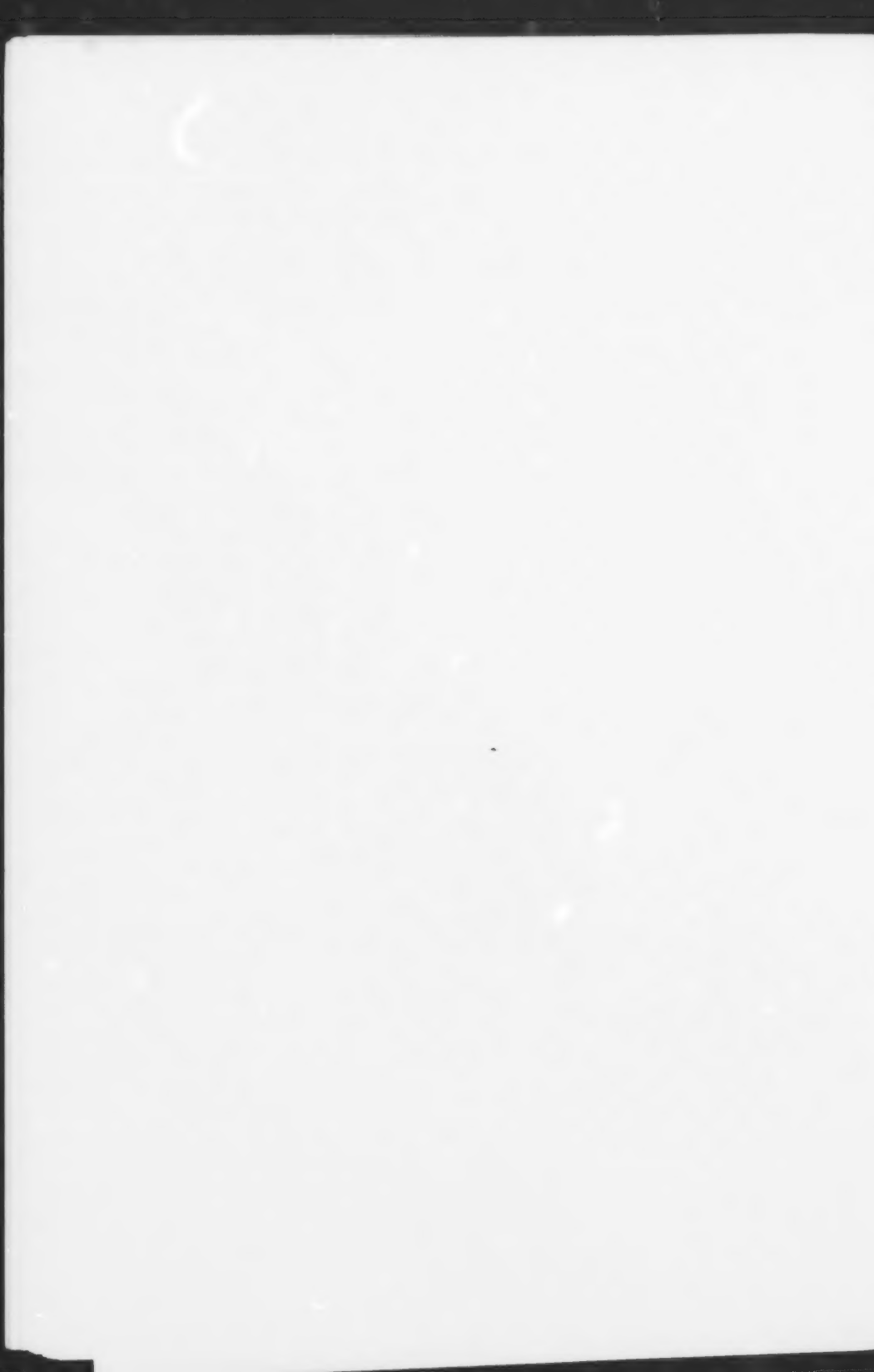
sortant de l'école ou jouant dans la rue. Celle-ci est la même et elle est multiple. Il peut en faire son lieu et sa forteresse et il peut aussi répondre à l'appel de la ville, aller à la rencontre d'une rue semblable pour découvrir son visage unique et multiple. La ville excite ma curiosité et l'apaise, même quand elle ne la satisfait pas. Sans en connaître la langue, j'en connais le caractère et, dans le visage du jeune garçon, je devine le possible itinéraire. Et je reconnais ma ville dans chacun de ses quartiers, je retrouve ma ville dans chacune des autres. Elles sont ma ville car je vis pleinement la mienne. A travers la mienne, je me retrouve dans chaque quartier, je reconnais le contour, j'en dresse une silhouette et je sais que, si je choisisais d'y rester, j'en connaîtrais le visage. Et cette ville étrangère, lointaine, cesse d'être terreur et inquiétude. Elle serait fraternelle si la peur ne persistait pas. Le regard de l'inconnu est menace et il faut du temps et de la patience pour le reconnaître et peut-être l'approvoiser. Et là il ne s'agit pas uniquement d'une ville étrangère.

Pour moi, le rapport avec l'au-delà débute et prend sa source dans le lien avec autrui. Le Prophète est seul quand il reçoit le message, mais la parole de Dieu n'a de sens qu'à partir du moment où il la transmet. Il est, d'ailleurs, appelé par l'auteur de la parole à partir, à aller à la rencontre des hommes. Il n'y a de parole que transmise même quand elle court le risque de ne pas être entendue. L'écrivain va toujours en ville même quand celle-ci-lui oppose silence et indifférence. Il n'a de cesse de frapper à la porte, de répéter sa parole, de réitérer sa demande d'être entendu. Il n'a de cesse de tenter de briser la cloison, de franchir la surdité. Il est seul et il parle dans la douceur et le hurlement, sachant que sa solitude ne peut être que momentanément vaincue, qu'il se retrouvera à nouveau devant la parole à inventer pour raconter l'histoire de la ville fut-elle silencieuse, parce qu'elle lui impose le silence.

La ville oppose au silence son bruit confus. L'écrivain se promène et regarde les visages. Fermés, inquiets ou débordants, maussades ou joyeux, ils racontent chacun une histoire. Dans la rue, la foule. Des solitaires à la recherche des autres ou les fuyant. Des couples. Des groupes. Des jeunes et des vieux. Les histoires se nouent, se déploient, entrent dans la période de conflit, de l'intensité et de la confusion. Elles se dégradent en confrontation, en guerre ouverte ou se dissipent dans un nouveau silence. L'écrivain entre dans la mêlée. Il vit sa propre histoire et la voit se confondre avec celle des autres. Il marche dans le brouillard et dans la confusion, cherche à se retrouver. Il raconte. La ville vit, l'absorbe, l'engloutit et le nourrit. Des hommes, des femmes se lient et se rejettent, et les histoires se déploient, multiples. Il n'a pas à comprendre. Il vit et la vie naît et renaît dans les histoires racontées. Il n'est pas un observateur lointain. Sa distance ne le sépare pas de la foule parce qu'il ne voit dans la multitude que des visages. Un par un. Des personnages et des histoires. Il se raconte par la ville car il la vit et la fait vivre de sa propre vie. Et il ressent la fatigue. Une trop longue confusion, un épais brouillard le décourageant. A constamment tenter de le franchir vainement l'exténue. Et il cherche refuge ailleurs. Où ? A la campagne ? Mais il ne peut pas fuir sans se renier, sans que sa

vie ne se disperse en pure perte, sans qu'il ne soit assailli par la léthargie de l'insensé. Et il revient. La campagne, c'est le chemin du retour. Elle indique la ville. Il n'y a pas d'oubli. Et tant que les histoires ne sont pas racontées, l'écrivain n'a de choix que de revenir et de recommencer.

Si la parole naît dans le désert, elle est entendue dans la ville. Les hommes qui y vivent peuvent lui opposer silence ou surdité, mais ils ne peuvent survivre sans que cette parole fasse écho. Des millions d'hommes peuvent être parqués dans une grande agglomération. Ils passent chacun à côté de l'autre. Leurs regards traversent l'étendue de leur espace sans qu'ils se rencontrent. Ils sont seuls, et rien n'arrive. Ils le croient. Jusqu'au moment où leurs histoires silencieuses, étouffées, voire inconscientes est racontée, leur est raconté. La vie surgit, prend forme. La ville prend naissance, puis disparaît avant d'être reconstruite. Le passage de l'écrivain suffit pour la reconstituer en mémoire, la sauver et sauver la vie des hommes de l'oubli.



ACADEMY II

**Academy of the Humanities
and Social Sciences**

**SYMPOSIUM:
WHY ARE CANADIANS DYING OUT?**

Why Are Quebecers Dying Out Even Faster Than Other Canadians?†

MOST DEMOGRAPHERS now agree that, except for some drastic, rapid—and unrealistic—changes in demographic behaviour, Quebec's population will start to decline around the turn of the century, and that this decrease in numbers will start sooner and will be more pronounced than that in the rest of Canada. Such an evolution would have been considered pure fiction only twenty years ago. The question is thus: To what extent has Quebec's society been so "distinct"—demographically speaking—as to lead to such a dramatic reversal?

Only after considering the three components of demographic behaviour: fertility, mortality and migration, and looking at briefly the projections that may be derived from this behaviour, can one assess the implications for policies.

I FERTILITY

At the end of the 1950s, Quebec had one of the highest fertility levels in the "developed" world: in 1959, its total fertility rate reached 3.9 children per woman, a figure almost identical to the one observed in the rest of Canada. Twenty years later, in 1979, the Quebec rate had dropped to 1.75, a drop of 2.2% a year. Over the last years, the decline in the fertility rate has accelerated: the 1985 rate is 1.42, a 3.2% annual decrease between 1979 and 1985. This 1.42 figure for Quebec is markedly lower than the corresponding figure, 1.75, for the rest of Canada.

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TABLE 1
Fertility according to region and home language. Quebec 1981

Total fertility rate	Francophones	Anglophones	Allophones
Montreal	1.33	1.34	1.68
Rest of Quebec	1.77	1.20	2.48
Total of Quebec	1.66	1.29	1.88
<i>Number of children ever born per woman aged 45 and over</i>			
Montreal	2.6	2.1	2.7
Total Quebec	3.6	2.4	2.8

The drop in Quebec's fertility is not less impressive if we look to the number of children ever born. Quebec women who had completed their fertility in 1943 or before had an average of 3.8 children. The generation born in 1943 was the last one which replaced itself (2.1 children per woman). The 1963 generation is expected to have 1.6 children per woman, and, as we have seen, the most recent generations will have only 1.4 children per woman, a deficit of one third, if they adopt the present fertility behaviour.

In order to understand—and project—fertility behaviour, one must look for disparities between subgroups of the population. A significant disaggregation is the one by region and linguistic group (defined according to home language). Because this kind of disaggregation requires population figures by age, sex, region, and home language, figures that may be obtained only from the census, computation could be made only for 1981, the latest census for which these data were available. Table 1 presents the 1981 total fertility rates as well as completed fertility to each of the three main linguistic groups (Francophones, Anglophones, and Allophones) and for the Montreal region (The Montreal and Jesus Islands) and the rest of Quebec.

The figures presented in Table 1 demonstrate how large fertility disparities may be, even within a province: while Anglophones out of Montreal had a total fertility rate of 1.20 in 1981, Allophones in the same region (mainly Inuit and Amerindians) had a rate twice as large; the latter group is the only one which is replacing itself, and also the only one showing a rate higher than the one observed in the rest of Canada. It is interesting to note that in the Montreal region, Francophones and Anglophones show the same fertility level (slightly above 1.3), with the Anglophones out of Montreal having an even lower rate (1.2). If we assume that linguistic disparities in the total fertility rate are the same today as in 1981, then one would be led to a level of 1.05–1.10 for Quebec's Anglophones in 1985. One may conclude that if, as has been the case in the past, the non-English population tends to adopt the fertility behaviour shown by the Anglophones, there could be a further decline from the present figure of 1.4.

The situation observed in the beginning of the 1980s, characterized by a

TABLE 2

Number of children ever born per woman, according to home language and age of woman, Quebec, 1971 and 1981

Home language and census year		Age group			
		20-24	25-29	30-34	35-39
French	1971	0.36	1.24	2.19	2.87
	1981	0.26	0.94	1.56	1.97
English	1971	0.34	1.15	2.01	2.48
	1981	0.20	0.72	1.42	1.88
Other	1971	0.63	1.42	2.02	2.40
	1981	0.46	1.28	1.93	2.35

Source: Statistics Canada, census data

marked over-fertility of the Allophones and under-fertility of the Anglophones, is quite different from the one shown by the generations who had completed their fertility by then: the figures for the average number of children ever born to women aged 45 and over in 1981 show that Francophones had in the past a fertility level much higher than that of the other groups, except in the Montreal region where Francophones and Allophones followed more or less the same behaviour.

The transition from Francophones' over-fertility to Allophones' over-fertility is clearly seen in the data produced in Table 2, which shows the evolution, between 1971 and 1981, of the number of children ever born per woman, according to home language and age of woman. At all ages, the rate of decline is the lowest among Allophones, while it is the highest for Anglophones (except for the 35-39 age group), closely followed by the Francophones. As a result, in 1981, the average number of children ever born is the highest among Allophones and the lowest among Anglophones, and this is true for each age group. The younger the generation, the higher are Allophones' over-fertility and Anglophones' under-fertility with respect to Francophones.

We may conclude from this brief analysis of fertility behaviour in Quebec that the population of this province does not insure by far—a one-third deficit—the replacement of its population, that its present fertility level is markedly lower (20%) than the one observed in the rest of Canada, and that, given the behaviour of some of its subgroups, there may be a further decline.

2 MORTALITY

Quebec has shown, for a long time, a marked over-mortality with respect to the rest of Canada. While in 1971 Quebec's life expectancy at birth was 68.2 years for males and 75.2 for females, the corresponding figures for the rest of Canada were 69.7 and 76.7 respectively, a difference of 1.5 years for both sexes. Ten years later, this difference had been reduced to 0.4 for females but was still 1.2

TABLE 3

Probability of dying (in per '000) during some age intervals, Quebec, 1980-1985

Age Interval	Males		Females	
	1980-1982	1985	1980-1982	1985
0-1	10.0	7.6	8.0	6.7
1-15	6.3	4.8	4.4	3.4
15-45	51.7	46.8	22.5	19.7
45-75	496.3	479.2	278.8	260.6

for males. The 1985 figures show that Quebec females have now almost the same mortality level as other Canadian females (79.7 compared to 79.9 years) while males still show the same 1.2 year difference (72.0 compared to 73.2 years).

In other words, in the last 14 years (from 1971 to 1985), life expectancy at birth has increased by 3.8 years for Quebec's males, with the gain for males in the rest of Canada being 3.5 years, a negligible difference. Over the same period, females gained 4.5 years in Quebec and 3.2 years in the rest of Canada. Sex "discrimination" with respect to death is thus increasing in Quebec, females having now 7.8 years advantage, up from 7.0 years at the beginning of the 1970s.

It should be emphasized that most of the recent gains in male life expectancy were made at the earliest ages of the life span. Indeed, while male life expectancy at birth increased by 0.9 years between 1981 and 1985, only 0.2 years of these were accounted for by gains at age 65. For females, however, significant gains were also made at older ages: life expectancy of Quebec women at age 65 increased by 0.5 years over the same period. Table 3 shows, for four age intervals, the extent of mortality decline between 1980-1982 and 1985. For males, the probability of dying during age intervals 0-1 and 1-15 decreased by as much as 24% over this period, but only by 3% in the age interval 45-75. Infant mortality declined less among females than among males, but for the 45-75 age group the rate of mortality decline was faster for females.

3 NATURAL GROWTH

As a result of these differences in fertility and mortality, natural increase dropped much more rapidly in Quebec than in the rest of Canada. Table 4 shows the changes in number of births and deaths, as well as the yearly rate of natural increase, for Quebec and the rest of Canada. Between 1959 and 1985, the number of births declined by 40% in Quebec and by 13% in the rest of the country, while the number of deaths increased at about the same rate in both regions (about 30%). In 1959, Quebec's annual excess of births over deaths was 109,000; in 1985 this natural increase had dropped to 40,000, a 63%

TABLE 4
Natural growth. Quebec and the rest of Canada, 1959-1985

	1959	1979	1985
<i>Births</i>			
(in '000)			
Quebec	144	100	86
Rest of Canada	335	266	290
<i>Deaths</i>			
(in '000)			
Quebec	36	42	46
Rest of Canada	104	126	135
<i>Natural Increase</i>			
(in '000)			
Quebec	109	58	40
Rest of Canada	231	140	155
<i>Yearly Rate</i>			
(in %)			
Quebec	2.2	0.9	0.6
Rest of Canada	1.9	1.0	0.8

decline. Over the same period, natural growth declined by "only" one-third in the rest of Canada. It seems important to note that while between 1979 and 1985 there was a marked acceleration in the rate of decline of Quebec's natural growth (from a yearly decrease of 2% between 1959 and 1979 to 5% between 1979 and 1985), in the rest of Canada the excess of births over deaths actually increased during the same period.

The picture looks even more dramatic if one considers the yearly rates of natural growth. In 1969 Quebec's rate was 2.2%, slightly higher than the one observed in the rest of Canada. Twenty years later the annual rate was less than 1% in Quebec, and today the rate has dropped to 0.6%, significantly lower than the one observed in the rest of Canada. In other words, if we disregard migration, Quebec is now close to "zero population growth," and the rest of Canada is following closely.

4 MIGRATION

To what extent does migration put a brake on or accelerate the "natural" evolution described in the previous sections? The figures of Table 5 provide a clear answer: migration makes things even worse for Quebec and improves a little bit the situation for the rest of Canada.

Indeed, in the long run, Quebec is constantly losing through migration, the small gains made through international migration being more than neutralized by the (sometimes huge) losses from interprovincial migration. Considering that the losses experienced by Quebec in its exchanges with the rest of Canada represent, by definition, gains for the latter, and that Quebec's share in the

TABLE 5

Growth from migration. Quebec and the rest of Canada, 1966-1981 (annual averages, in thousands)

Census period	Interprovincial	International		Total	
		Quebec	Rest of Canada	Quebec	Rest of Canada
1966-1971	-25	5	79	-20	104
1971-1976	-16	9	88	-6	104
1976-1981	-31	11	51	-20	82
1981-1986	-16	10	42	-6	58

Source: Statistics Canada, annual estimates.

gains from international migration are always smaller than its share in the total population of Canada, one cannot but conclude that migration increases the disparities between Quebec and the rest of Canada as far as the trend toward population decline is concerned.

One should mention that, at least for the last 15 years, Quebec's gains from international migration are remarkably constant, averaging 10,000 people a year, compared to the 40,000 figure for natural increase in 1985. The implication is that international migration is taking and, according to all projections will continue to take, an increasing role in shaping Quebec's demographic profile. However, to obtain this annual gain of about 10,000 people, Quebec had to receive about 20,000 immigrants a year.

Actual levels of international migration to Quebec are relatively low (an annual average of 17,000 immigrants in 1981-1986), but they have been lower (13,000 in 1961-1962). They also have been much higher, but only in very exceptional cases: actually, over the last 30 years, the number of international immigrants in Quebec has been significantly larger than 40,000 only once (in 1966-1967, in a time of economic expansion and high fertility, with a 45,000 figure).

If gains from international migration are thus relatively constant, at least if we consider five-year census periods, the same is not true of interprovincial migration. The latter seems to be more cyclical, with huge annual losses (in the 25-30 thousand range) in 1966-1971 and 1976-1981, and small losses in 1971-1976 and 1981-1986 (a little more than 15,000 a year). There are large variations around these five-year averages. In 1961-1962, Quebec even experienced a small gain in its exchanges with the rest of Canada, a performance which apparently has been repeated in 1986-1987. On the other hand, the largest net loss experienced by Quebec was 46,000 in 1977-1978.

These considerations lead us to what may be viewed as the dominant feature of Quebec's interprovincial migration behaviour. If, as in Table 6, we disaggregate these migration flow according to language, then it is seen that (with a remarkably low and constant annual rate of outmigration of two per

TABLE 6

Yearly migration rates (in per '000) between Quebec and the rest of Canada, according to mother language, 1966-1981

	French	English	Other
<i>Quebec to</i>			
<i>Rest of Canada</i>			
1966-1971	2	27	10
1971-1976	2	25	7
1976-1981	2	39	10
<i>Rest of Canada</i>			
<i>to Quebec</i>			
1966-1971	8	1	-
1971-1976	9	1	1
1976-1981	7	1	1

Source: Statistics Canada, census data

TABLE 7

Yearly net interprovincial migration rates (in per '000) according to mother language, 1966-1981

	French	English	Other
<i>Quebec</i>			
1966-1971	-0.6	-14.1	-6.8
1971-1976	-0.2	-13.8	-3.6
1976-1981	-0.7	-32.2	-8.6
<i>Rest of Canada</i>			
1966-1971	3.2	1.0	1.0
1971-1976	1.0	0.9	0.6
1976-1981	4.2	1.7	1.3

thousand) Quebec's Francophones actually do not consider the rest of Canada as being part of their "action space," while the propensity to leave for the rest of Canada is 13, even sometimes (1976-1981) 20, times higher among Anglophones. On the other hand, Anglophones from the rest of Canada do not consider Quebec as being part of their action space either. Quebec's migration problem is thus a problem only for Anglophones, who easily leave Quebec for the rest of Canada, but who do not want to enter it. Quebec's Francophones seem to be totally disconnected from the rest of the country at least as far as migration is concerned.

If, instead of considering propensities to move between Quebec and the rest of Canada, we look, as in Table 7, to the resulting gains and losses, that is, net migration by linguistic group, then it is clear that interprovincial migration has a negligible impact on Quebec's French group, but a marked one on the English group: the latter loses each year between 1.4% and 3.2% of its population, only because of interprovincial migration. Those large losses do, however, represent only a very small rate of increase for the English group in the rest of Canada (about 1% a year).

TABLE 8

Probability (in %) of surviving in region of birth, according to home language, 1976-1981

Region of birth and language	Probability of surviving there until exact age		
	20	35	65
<i>Quebec</i>			
French	95	91	71
English	45	19	7
Other	89	77	56
<i>Rest of Canada</i>			
French	70	53	38
English	97	95	79
Other	97	95	78

The marked disparities in the migration rates of Quebec's linguistic groups have some important implications. One should indeed not forget that migration is much more than the spatial transfer of individuals. It also implies the transfer of "years to live" and "babies to be born" from these individuals. If we combine migration and mortality, and compute the probabilities of surviving in the region of birth until some exact age, then we obtain an estimate of the capacity of a region to retain its new-born population during its most (re)productive ages. Table 8 shows these probabilities for each of the three main linguistic groups with reference to three exact ages: age 20 (beginning of the most reproductive years and entry in the labour market), age 35 (end of the most reproductive years) and age 65 (end of the productive years).

According to the migration and mortality regime observed in 1976-1981, more than half of the new-born members of the English group will already have left Quebec by age 20, only one-fifth of them will still be in Quebec at age 35, and a very small minority (7%) will spend the whole of their (re)productive years in their province of birth. Almost all of Quebec's Francophones will, however, spend their most reproductive years in Quebec, with 70% still being in their province of birth at the end of their working life. The rest of Canada has an even higher capacity of retaining its English-"speaking" new-borns.

Another way of looking at this retention problem is to disaggregate life expectancy at birth according to the region of residence. Table 9 shows the results for each linguistic group. A baby born in Quebec among the French group may expect to live a little more than 72 years, of which less than 4 years, that is 5%, will be spent in the rest of Canada. If this baby is born among Quebec's English group, she or he will spend only 22 years in Quebec; in other words, about 70% of her or his life will be spent in the rest of Canada. If the same baby had been born among the Anglophones (or Allophones) of the rest of Canada, then she or he would spend less than one year in Quebec.

These transfers of life expectancies imply also transfers of "expected

TABLE 9

Life expectancy at birth, according to region of birth and residence, and home language, 1976-1981

	Region of residence			
	Quebec	Rest of Canada	Total	Percentage Exported
<i>French</i>				
Region of birth:				
Quebec	68.6	3.7	72.3	5
Rest of Canada	29.7	43.3	73.0	41
<i>English</i>				
Region of birth:				
Quebec	22.0	52.7	74.7	71
Rest of Canada	73.4	0.7	74.1	1
<i>Other</i>				
Region of birth:				
Quebec	60.5	16.2	76.7	21
Rest of Canada	1.1	73.1	74.2	1

babies." If we compute net reproduction rates according to the region of birth of these babies, then one discovers that, according to the 1976-1981 fertility, migration, and mortality regime, about 75% of the (rare) babies expected to be born from an Anglophone born in Quebec will actually be born outside Quebec, while almost all babies expected to be born from a Francophone born in Quebec will be born in the province of birth of his parents, just as almost all babies expected to be born from an Anglophone born in the rest of Canada will also be born in the rest of Canada.

5 PROJECTIONS

A decline in the number of people residing in Quebec now seems inevitable. All recent projections agree on this. The only disagreement relates to the timing of the decline: the most pessimistic scenarios lead to a decline starting around the turn of the century, and the more optimistic ones (if we exclude a sudden and unrealistic return to replacement level) conclude that the decline might be postponed for about 20 years more. Table 10 presents the results of the most recent projections made by the Bureau de la Statistique du Québec (BSQ) in 1984 and Statistics Canada (sc) in 1985.

In both cases, the "minimum" scenarios assume a total fertility rate of about 1.4 in the 1990s, the BSQ being even more pessimistic than sc: the latter assumes the rate will reach 1.35 only in 1996 while the BSQ considers that this level will already be observed in 1986. Despite this, sc concludes that the decline could start just before the end of the century, while BSQ considers it could happen just after the year 2000. This small difference is mainly the result of sc's assumption of a continuing westward migration flow, leading to relatively large losses through interprovincial migration for Quebec.

TABLE 10
Various projections of the Quebec population (in thousands) 1986-2026

	1986	1996	2001	2006	2011	2021	2031
<i>Minimum</i>							
BSQ (1984)	6585	6737	6739	*6708	6640	6386	5981
SC (1985)	6627	6780	*6741	6658	--	—	—
<i>Average</i>							
BSQ (1984)	6611	6965	7065	7127	7158	*7120	6918
SC (1985)	6630	6862	6876	*6844	—	—	—
<i>Maximum</i>							
BSQ (1984)	6617	7142	7400	7612	7779	8057	8219
SC (1985)	6634	7117	7347	7528	—	—	—
<i>Probable</i>							
SC (1985)	6627	6879	6904	*6881	—	—	—

Note: The * sign indicates the beginning of population decline. BSQ refers to the Bureau de la Statistique du Québec, and SC to Statistics Canada.

The "average" scenarios of both statistical agencies are also very similar as far as the fertility assumption is concerned, with, in this case, the BSQ being more optimistic than SC: the latter assumes a fertility rate slightly below 1.6 by 1996, while the BSQ considers this level will already be reached in 1986 (this hypothesis has already been invalidated: as mentioned earlier, the 1985 rate was 1.42; tentative estimates for 1987 lead to a figure below 1.40). Even with the BSQ's over-optimistic and unrealistic assumption of a sudden increase to a 1.60 rate (since 1986), one is led to conclude that a decline will start sometime during the second decade of next century, some 30 years from now. If we consider instead SC's "average" scenario assuming a gradual increase from the present 1.4 rate to a 1.6 figure in 1996, then the decline starts, as in the BSQ's most pessimistic scenario, just after the year 2000. Statistics Canada's "most probable" scenario is only slightly different from this "average" scenario, and also leads to a decline starting in the first years of next century.

As an academic exercise, one may also consider the most "optimistic" scenarios, again very similar as far as fertility is concerned. In these scenarios, both the BSQ and SC assume that fertility will rapidly increase, reaching replacement level (2.1) as soon as 1996, and remain constant afterwards. In this highly unlikely (if not utopian) situation, Quebec will of course—by definition—avoid a decrease in the number of its inhabitants. Instead, the population of Quebec would in this case be about one million larger than the population projected on the basis of the most pessimistic scenarios.

The evolutions which may be expected for the Quebec population have obviously important implications as far as the age structure of this population is concerned. Table 11 presents these projected age structures. The figures there produced show that, even in the most optimistic scenarios, by 2026 the number

TABLE 11
Projected age structure, Quebec, 1986-2026

	1986 (Observed)	2001 (Min-Max)	2026 (Min-Max)
0 to 14 age group (%)	21	17-19	13-19
65-and-over age group (%)	10	13-14	20-24
Dependency ratio* (%)	45	43-49	49-75
Mean age (number of years)	34	38-39	40-45
Median age (number of years)	32	40-45	39-46

*The dependency ratio is obtained by relating the sum of the percentages of the 0-14 and 65-and-over population to the percentage of the population aged 15-64.

of people aged 65 and over will be larger than the number of people aged 0-14, and their percentage in the total population will be twice the percentage observed today. If the dependency ratio is not expected to change much before the turn of the century (because the baby-boom generation will still be members of the working age groups), by the year 2026 there most probably will be a marked increase in the ratio. According to the most pessimistic scenarios, we may even expect a situation where there are three dependents (aged 0-14 and 65-and-over) for each four people in the 15-64 age group. Actually the dependency ratio could very well be close to one (one dependent for each member "at work", because some members of the 15-64 age group (students, unemployed, etc.) will in reality be "dependent."

Mean and median ages will increase markedly, even over a relatively short period. By the turn of the century, the mean age will be close to 40 years (up from the 34 years observed today), and at least 50% of the population will be older than 40 years. A quarter of a century later, around the year 2026, the mean age of the population will be about 10 years higher than today.

A society which is declining in numbers, where the percentage of people over 65 is twice that observed today, where each member of the labour force has to support one "dependent," a society which has experienced a rapid increase in the mean age of its population (10 years over a 40 year period), and where half of this population is older than 45 years, will face serious social and economic problems.

Such a situation is not expected to occur in the foreseeable future in the rest of Canada (taken as a whole). Even according to Statistics Canada's most pessimistic scenario, the total population of the country would not start to decline before the year 2015 (twenty years later than in Quebec), and by the year 2026, the annual decrease would still be only slightly above 100 thousand. Quebec would by then have a much larger decrease, so that one may still expect an increase in the Canadian population outside Quebec. As a result, Quebec's share within the total population of Canada will be decreasing rapidly: from the present 25.8%, Quebec's share is expected to decline to 23.5% by the year 2006 if the most pessimistic scenario prevails, and to 24.5% under the most

optimistic (but as we have seen, highly unrealistic) scenario. Extrapolating such an evolution would imply that by the year 2050, Quebec would represent markedly less than 20% of Canada's total population. The socio-political consequences of such a change should not be underestimated.

6 "CAUSAL" RELATIONS AND POLICY IMPLICATIONS

A demographic answer to the question "why are Quebecers dying out even faster than other Canadians" is not difficult to obtain. Quebecers are "dying out" faster because their fertility level is much lower than the one observed in the rest of Canada; they still show—even today—slightly higher mortality rates; they are losing population by interprovincial migration in favour of the rest of Canada, and their share in international migration gains is much smaller than their share in the total population. Quebec is therefore losing ground in all four of the demographic components of growth.

It may even be said that if the question of demographic decline arises in Canada, it is essentially because of Quebec. Indeed, as we have seen, with a 1.8 fertility rate and with a relatively small inflow of international migrants, the rest of Canada should be able to avoid a decrease in its population. With a 1.4 fertility rate in Quebec, the situation and the prospects are quite different. The question is therefore not so much "Will Canada be able to avoid population decline?" but rather "Will Quebec be able to avoid population decline?"

To answer such a question one needs much more than a demographic explanation in terms of fertility, mortality, and migration. We need to explain why Quebec has experienced a much higher rate of fertility decline than the rest of Canada, why Quebec has higher mortality rates, why Quebec is losing people by interprovincial migration, and why Quebec's share in international migration is smaller than its share in the total population of Canada.

As far as migration behaviour is concerned, some elements of an answer have been provided. For instance, we have seen that Quebec's loss through interprovincial migration is mainly due to the behaviour of Anglophones, who easily leave Quebec but do not enter it. Such behaviour seems to be much more related to socio-cultural and political considerations than to economic ones. The same kind of conclusion could probably be derived concerning international migration.

The main explanatory gap concerns fertility. There has not, until now, been a satisfactory explanation for the decline in fertility in developed countries, and the most reasonable explanations are difficult to prove. Of course, there is the well known "Easterlin hypothesis," which considers that economic conditions (more precisely, intergenerational differences in supply and demand of labour) are the crucial determinants of fertility. Such an approach could perhaps explain a large part of fertility behaviour in the past, but it was not able to forecast the decline in fertility at the beginning of the 1960s, or the continuation of this decline over the last 25 years. Moreover, since the beginning of the

1960s, there is a quite new phenomenon to be considered, mainly the fact that for the first time in history human societies (at least the most developed ones) have at their disposal the technical means to control (almost) totally their fertility, and this technological revolution occurred simultaneously with a real socio-cultural revolution, characterized by the disappearance of most social constraints and institutionalized attitudes. The least that could be said is that this new scale of individualistically oriented values is far from encouraging the arrival of children.

If the roots of the fertility problem were more economic than socio-cultural, then there would be some hope for a rapid and significant increase in fertility in the near future. But if—as seems probable—the fertility problem, like the problems related to divorce, abortion, status of women, etc., is only part of a much wider process of socio-cultural change, then an amelioration of labour market conditions will not suffice to reverse the fertility trend, nor will a few pronatalist policy measures.

Some peculiarities of present fertility behaviour in Quebec should not be ignored when considering the demographic future of this province and the possible impact of policy measures intended to change the "natural" course of things. Almost half of births occurring today in Quebec are births of rank 1, and more than 80% are of rank 1 and 2. Births of rank 3 and more represent only 0.24 points of the 1.42 total fertility rate observed in 1985. Almost 80% of mothers of first-borns are in the 20–29 age group, and 70% of all births occur from a mother in this age group (90% are from mothers aged 20–34). The total of female sterilizations, hysterectomies and vasectomies has averaged about 60,000 a year over the last decade, and remains fairly stable. The mean age of female sterilization is 34 years, and more than half of female sterilizations are of women aged less than 35 years (20% are under 30). If the present rate of sterilization per age remains constant, almost half of all women and one-third of men would be sterilized, and one-third of women would have an hysterectomy before age 50.

All these considerations imply that the burden of any fertility increase will have to be borne by a small minority of the total population, mainly those women who are aged 20–29, who are not yet sterilized, who may expect a relatively stable "matrimonial" and economic situation, etc. Quebec women aged 20–29 now give birth each year to about 60,000 babies, and if we add those aged 30–34, the total is 78,000. To insure the replacement of the population, they should give birth to about 35,000 more babies. One may wonder whether it is reasonable to ask this small minority of the population to increase its fertility contribution by 50%. Some marked changes will have to take place in the functioning of our socio-economic system, and some remarkable modifications will have to occur in our present scale of values, before a positive answer to this question can be given.

The Review of Demography and Its Implications for Economic and Social Policy: Will It Deliver Building Blocks for a Population Policy?[†]

MANDATE AND ACTIVITIES OF THE REVIEW

THE FEDERAL CABINET, concerned about the long-term outlook for the size and structure of Canada's population, decided to clarify the scientific basis for addressing population issues. To this end, they asked the Honourable Jake Epp, Minister of National Health and Welfare, in April 1986, to review the empirical evidence for relationships between demographic and other social and economic variables; to evaluate, extend and integrate this evidence so as to contribute to the review of specific issues by the government and the general public; to bring to bear the best scientific work to elucidate effects on programs and policies; and to report by 31 March, 1989.

The principles governing the Review's work are simple. Its purpose is to give policy makers additional social-science knowledge, publicly judged and accepted, so that they can address long-term interactions between population change and economic and social change. It is multidisciplinary, and for most of its work makes use of the resources of the academic community. All the research that it supports is on the public record; researchers are encouraged to publish their work in the scientific literature. Mr. Epp wrote in June 1986 to the presidents of more than forty universities and colleges across Canada, requesting assistance in the initial, issue-defining, phase of the Review. This phase resulted in the preparation of more than 120 issues papers.¹ Special

* Secretary, Review of Demography and Its Implications for Economic and Social Policy, Government of Canada.

[†] Presented at the Symposium "Why Are Canadians Dying Out?" University of Windsor, 7 June, 1988.

¹ A full account of the Review's first phase will be found in: Canada. Health and Welfare Canada. *Posing the Questions: Review of Demography and Its Implications for Economic and Social Policy*, Ottawa: Supply and Services Canada, 1987. The first-phase papers with the greatest influence on the Review's work were published in a special issue of *Canadian Studies in Population*, Volume 14 (2), 1987.

efforts were made at all stages to contact women researchers to inform them of the Review and to enlist their participation in it. The Minister also wrote to the heads of national businesses, labour, and ethno-cultural organizations as part of a programme to encourage all interested groups to participate in defining the issues and shaping the research program.

To fill the gaps in knowledge identified in the first phase, a formal request for research proposals was issued on 31 March, 1987. From the ninety-five proposals received, twenty-one research projects were selected, based on advice from an advisory committee convened by the Royal Society of Canada and chaired by Professor Karol J. Krótki, from an expert working group of Statistics Canada, from experts in issues affecting women, and from federal officials. Subsequently, small research projects have been commissioned on aging, economic growth, and ethno-cultural groups.

WHAT IS A POPULATION POLICY?

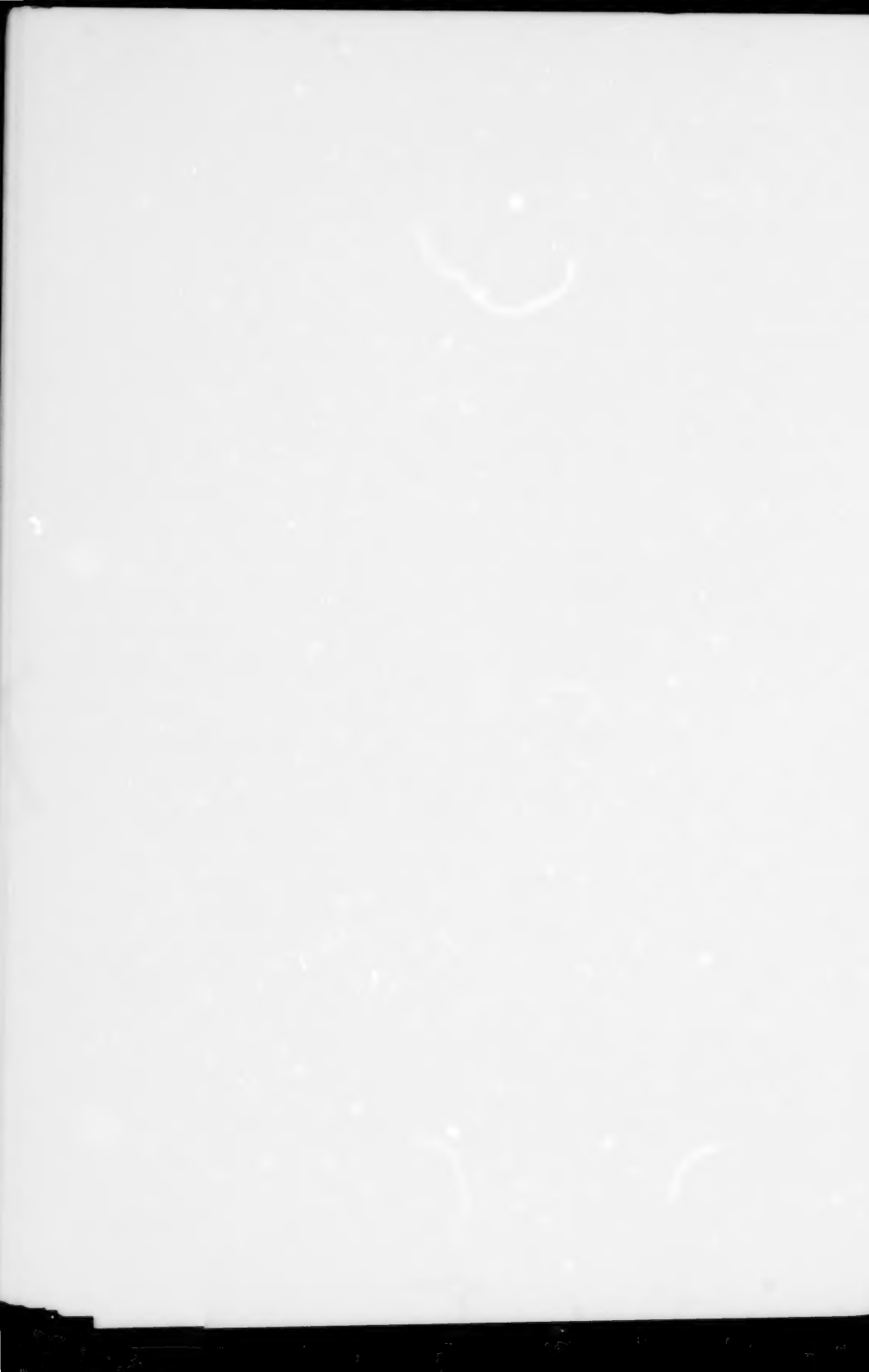
There is no generally accepted definition of a population policy. Any policy affecting fertility, mortality, or migration with the aim of maintaining or altering the size, structure, or composition of the population could be considered a population policy. Policies affecting immigration, health care, family benefits, housing costs, and women's job security, to mention only a few examples, could be part of a population policy. It may be unclear whether a policy is intended as a population policy, and there may also be disagreement as to the population effects of a policy, whether or not it is intended as a population policy. It is often not possible to say whether a country has a population policy. Even France, which is generally considered the most population-conscious of Western nations, the nation if any to have a population policy, has seen two recent official studies calling on the government to adopt explicit natalist or family policies.² In the past thirty years, some seventy population studies have been commissioned in twenty-four developed countries. Their findings show little consensus: for example, both positive and negative conclusions are reached about the relationship between population growth and economic growth. There is equal diversity in their policy recommendations and no consensus as to what constitutes a population policy.

WILL THE REVIEW PRODUCE BUILDING BLOCKS FOR A POPULATION POLICY?

When the Review reports to cabinet in March 1989, it will present and analyze all available evidence, both that already existing and that produced by its research program. This is evidence related to changing household and family

² France. Haut Comité de la population, *Rapport de synthèse des travaux*, Paris: Documentation française, 1980; France, *Actes du colloque national sur la démographie française*. (INED, Travaux et Documents, cahier no. 92), Paris: Presses Universitaires de la France, 1981.

structures, population growth and economic growth, regional development and migration, the changing character of Canadian society due to an aging population and immigration, and international population movement. In short, it will present the building blocks for a population policy. The role of the Review, however, is to provide the building blocks for policy. It is up to the government of Canada, and more generally the people of Canada, to decide what structure, if any, should be built from these blocks.



Developments in Reproductive Technology: Medical Aspects[†]

INTRODUCTION

THE APPLICATION of reproductive technology to the treatment of human infertility took a major step forward with the birth of Louise Brown in 1978, the world's first human baby conceived outside the body of its mother. This important achievement, the result of over a decade of intensive efforts on the part of Drs. P.C. Steptoe and R.G. Edwards (1978), was the culmination of scientific contributions of a great many clinicians and scholars from many disciplines, spanning three centuries.

The technology of *in vitro* fertilization (IVF), in its modest beginnings, was seen as offering hope, for the first time, to countless infertile women who were desperate to have children of their own, but who could not because of irreversible damage to their fallopian tubes, either through disease or tubal sterilization. As experience has been gained with this new technology during the last decade, it has become evident that infertility due to several other causes, including infertility of the male partner, can also be treated by IVF and related procedures with some degree of success.

Current estimates of the incidence of infertility among couples of child-bearing age who wish to have children range from 15–20%. With increasing evidence that at least a proportion of these might be able to benefit from treatment with IVF or one of the related emerging technologies, infertility clinics have burgeoned in most developed countries and in many developing ones. In North America these clinics now number in the hundreds, including at least fifteen in Canada currently offering this "high tech" treatment. Waiting

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[†] Presented at the symposium, "Why Are Canadians Dying Out?" University of Windsor, 8 June, 1988.

TABLE I

Some landmarks in the development of reproductive technology

1677	Discovery of spermatozoa	(Leeuwenhoek)
1770s	First documented artificial insemination of woman with husband's sperm	(Hunter)
1827	Discovery of mammalian egg	(von Baer)
1890	First successful embryo transfer, rabbits	(Heape)
1931	Identification of pituitary gonadotrophic hormones, FSH and LH	(Fevold <i>et al.</i>)
1936	Identification of the female sex hormone, oestradiol-17 β	(MacCorquodale <i>et al.</i>)
1958	Documentation of clinical efficacy of steroidal oral contraceptive in humans	(Pincus <i>et al.</i>)
1959	First successful <i>in vitro</i> fertilization, rabbits	(Chang)
1977	First successful human <i>in vitro</i> fertilization; birth of Louise Brown in 1978	(Steptoe & Edwards)

lists as long as three to five years are claimed by many of these clinics. The purpose of the present report is to give an overview of the application of sperm- and egg-oriented technology in treatment of human infertility, along with some estimates of the rates of success which might be expected, based on results obtained over a four-year period, in a Canadian infertility clinic with which the author has been involved.¹ In addition, some current and possible future applications of these technologies, in areas not directly related to infertility, are presented.

SPERM-ORIENTED TECHNOLOGY: TREATMENT OF MALE INFERTILITY

Although accurate estimates are not available of the extent to which male factors contribute to the infertility of couples unable to conceive, estimates as high as 50% seem reasonable. Factors include inadequate sperm numbers, low semen volume, poor motility, viability and penetrating capacity of sperm, and abnormalities in sperm morphology. These conditions only rarely respond to hormonal therapy or other medical treatment. Until recently, the only option for conception in such couples was artificial insemination of the wife with donor semen.

Because of the greatly reduced numbers of sperm needed to fertilize eggs *in vitro* compared to *in vivo* by either natural or artificial insemination, *in vitro* fertilization is being used increasingly as a technique for permitting conception in couples in which the male partner is severely oligospermic, i.e., has a sperm concentration of <10 million spermatozoa/ml semen. The procedures used for preparing sperm for IVF select only the most motile of spermatozoa. Spermatozoa selected in this way have been used, sometimes successfully

¹ University Hospital, London, Ontario, *In Vitro* Fertilization Program.

TABLE 2

Artificial insemination: variation in procedures

Site of Semen (or Sperm) Deposition	Estimated sperm number to achieve conception (in millions)
Vaginal (AI or coitus)	50-500
External cervical os	10-20
Intrauterine	1-2
Intra-fallopian	0.1-0.2

(depending on the degree of oligospermia), for artificial insemination in which the sperm are placed either in the uterine cavity via transcervical catheter, or directly into the fallopian tubes, using laproscopic techniques.

The approximate numbers of motile spermatozoa required for fertilization when deposited at various sites within the female genital tract are presented in Table 2.

EGG-ORIENTED TECHNOLOGY: TREATMENT OF MALE INFERTILITY

Techniques of oocyte manipulation, used in conjunction with standard IVF procedures, offer promise of achieving fertilization with still fewer spermatozoa, and perhaps with sperm having reduced motility or other abnormalities. Sperm which succeed in reaching the site of fertilization following natural or artificial insemination still encounter additional barriers in the form of several layers of cellular and acellular coatings surrounding the egg, which must be penetrated in order to effect fertilization. A technique has been described recently, referred to as "zona drilling" in which the zona pellucida barrier surrounding the oocyte is partially digested by topical application of a weak acid to its surface by means of a blunt micropipet, making sperm penetration easier (Gordon & Talansky, 1986). Results with laboratory rodents indicate that the number of sperm required for *in vitro* fertilization of eggs treated in this way may be reduced by as much as 90% or more.

In a further extension of the same concept, methods have been reported for direct deposition of a single spermatozoa beneath the zona pellucida by means of a sharp micropipet (Laws-King *et al.*, 1987; Manns, 1988). With this procedure, the number of spermatozoa required for fertilization may approach the theoretical limit of one sperm per egg.

Mouse eggs successfully fertilized by both these methods of oocyte manipulation have been reported to undergo normal development when transferred to appropriate recipient females. If human embryos produced by these techniques prove to be similarly free of abnormalities, it is likely that zona drilling and sperm injection will be added to the growing battery of techniques available for treatment of male infertility.

TABLE 3

In vitro fertilization: effect of oocyte manipulation

Manipulation Method	Estimated sperm number to achieve fertilization (in thousands)
Standard IVF techniques	20-50
IVF following zona drilling	2-5
IVF by sperm microinjection	1

Estimates of the approximate number of spermatozoa required for fertilization using *in vitro* fertilization following oocyte manipulation are summarized in Table 3.

EGG-ORIENTED TECHNOLOGY: TREATMENT OF FEMALE INFERTILITY

In Vitro Fertilization - Embryo Replacement (IVF-ER)

Although developed initially for overcoming infertility due to blocked or absent fallopian tubes, IVF and embryo replacement is frequently used now for treatment of infertility due to other causes, including endometriosis, male factors, and idiopathic infertility (infertility of unknown etiology). The clinical and laboratory procedures involved have been the subject of many publications and reviews (e.g., Wood and Trounson, 1984), and therefore will be presented here only in abbreviated summary form in Table 4.

We have been operating an IVF-ER program at University Hospital, London, Ontario, since January 1984, following procedures essentially as summarized in Table 4. During the ensuing four years, until the end of 1987, we have initiated a total of 1329 treatment cycles, which represent 136 cycles the first year, increasing to 495 cycles in 1987.

Pregnancy, confirmed by positive β -hCG occurred in 171 of these cycles, i.e., in 18% of patients undergoing embryo replacement, or in 13% of cycles in which treatment was initiated. Twelve of these pregnancies miscarried before detection of a fetal heart beat on ultrasonic scan. Forty-three pregnancies, or 25% were lost either by spontaneous abortion or by termination of ectopic pregnancies or (in one instance) of a pregnancy exhibiting fetal chromosomal abnormalities (trisomy 21). Thus, the "take-home-baby" rate was 14% of patients receiving embryo replacement, per cycle.

Expressed on the basis of numbers of oocytes collected and embryos replaced, of 5293 oocytes recovered at laparoscopic or ultrasonic collection, 2677, or 50% were replaced as embryos after IVF (Table 6). The remaining 50% either failed to undergo normal fertilization or exhibited morphological abnormalities, and were discarded. Two hundred and four of the embryos which were replaced initiated implantation, demonstrated by ultrasonic scan

TABLE 4
Standard Procedures of IVF-ER

- 1 Hormone treatment to induce Multiple Follicle growth
- 2 Cycle monitored by hormone assays and ovarian ultrasonography
- 3 hCG injection at time indicated by monitoring, to initiate final phase of oocyte maturation
- 4 Oocyte retrieval by laparoscopy under general anesthesia or by ultrasound-guided aspiration needle under sedation and local anesthesia
- 5 Oocyte(s) cultured 4–5 h to complete maturation
- 6 Sperm collected by masturbation, assessed and processed for insemination
- 7 *In vitro* insemination: 10 000–50 000 sperm per oocyte
- 8 Assess fertilization microscopically, 16–18 h later
- 9 Continue culture of (fertilized) zygotes for 1–2 days, to 2–80-cell stage of embryo developed
- 10 Replace embryo(s) in donor via transcervical catheter or freeze for future use

TABLE 5
Summary of IVF results by patients, University Hospital, London, January 1984–December 1987

	Total	%
No. of treatment cycles initiated	1329	
No. of patients to oocyte retrieval	1176	88
No. of patients yielding oocytes	1131	96
No. of patients to embryo replacement	951	84
No. of patients initiating pregnancy	171	18
No. of patients delivered or continuing normal pregnancy	128	14
No. of patients undergoing miscarriage or termination	43	4

TABLE 6
Summary of IVF results by embryos, University Hospital, London, January 1984–December 1987

	Total	%
No. of oocytes recovered	5293	
No. of oocytes fertilized	3062	58
No. of embryos replaced	2677	87
No. of embryos implanting (visible by ultrasound)	204	8
No. of babies delivered (or continuing normal gestation)	160	78 (or 6% of embryos replaced)
Embryonic losses after transfer	2517	94% of embryos replaced
Embryonic losses after implantation	44	2% of embryos replaced

and positive β -hCG response, and 160 have been delivered as full-term babies, or are continuing as apparently-normal pregnancies. This represents an implantation rate of 8% of embryos replaced, and a 6% "take-home-baby" rate per embryo transferred.

These statistics compare favourably with those reported in the literature by most other centres in the world, for overall unselected results. It is evident that while a significant proportion of treated couples are able to achieve pregnancy

with this technology, most fail to do so on any single attempt. Results published recently from the Jones Institute for Reproductive Medicine, Norfolk, Virginia, indicate that pregnancy rates above 50% can be expected for couples willing to persevere for as many as five attempts (Guzick *et al.*, 1986). As will be discussed below, new techniques involving multiple egg collection, embryo cryopreservation and single and twin embryo replacements may be expected to produce similar results from a single cycle of treatment and oocyte collection.

Gamete-intra-fallopian Transfer (GIFT) and Zygote-intra-fallopian Transfer (ZIFT)

Since the development of the original IVF-ER procedures, these have undergone certain modifications or simplifications which have been found advantageous in the treatment of infertility in women with normally patent fallopian tubes. The first of these, the "GIFT" procedure, involves retrieval of eggs and preparation of spermatozoa as if for IVF-ER, but with immediate placement of the gametes (sperm and eggs) together in the fallopian tube via laparoscopy, thus bypassing the *in vitro* steps (Asch *et al.*, 1986). With this procedure, fertilization occurs in its normal site, but because the spermatozoa are placed in immediate contact with the eggs in the fallopian tube, fertilization can occur with sperm numbers much lower than would be required if insemination had occurred at the normal vaginal site.

Another modification of the standard IVF procedure, the "ZIFT" procedure involves gamete preparation and culture to permit fertilization *in vitro*, followed by placement of the resulting zygote (one-cell, pronuclear stage embryo, before cleavage) directly into the fallopian tube. Thus, although fertilization occurs *in vitro*, subsequent cleavage of the recently fertilized oocyte occurs in the fallopian tube. As with GIFT, this procedure requires the presence of normally functioning fallopian tubes. It is thus designed primarily to achieve pregnancy where sperm numbers are greatly deficient or where abnormalities of the oviduct prevent it from picking up the ovulated oocyte from the ovarian surface.

Oocyte and Embryo Donation

The hormonal stimulation regimens used to enable oocyte collection for purposes of IVF-ER frequently result in the production of more embryos that are desirable to replace, for fear of causing multiple pregnancies. Ethical dilemmas result, concerning the most appropriate use or fate of the excess embryos. A use ethically acceptable to most is the donation of surplus eggs or embryos for use by other infertile women who are unable to produce their own.

In the case of donated oocytes, these would ideally be fertilized with sperm from the partner of the woman who would receive them. This situation is similar to the use of donor semen in artificial insemination, in that the child born by the mother would be the genetic progeny of only one of the partners.

Embryo donation is, logistically, a somewhat simpler way of using excess

embryos to enable a third party to achieve pregnancy. Since neither the woman who gestated and bore the child resulting from an embryo donation, nor her partner, would be the genetic parent of the child, this situation represents a form of "pre-implantation adoption."

Oocyte donation can also be extended to permit surrogate motherhood, in that a woman with functional ovaries but lacking a uterus or otherwise unable to complete a gestation may produce her own genetic offspring. The egg from the woman would be fertilized by IVF using sperm from her partner. The resulting embryo would then be transferred to a "third party" who would carry the embryo to term as its "gestational" mother, and return the baby to the genetic parents, the donors of the egg and sperm.

GAMETE AND EMBRYO CRYOPRESERVATION

Cryopreservation of spermatozoa has been used in therapeutic donor insemination (TDI) programs for many years. Although some loss in pregnancy rate may be expected compared to that which can be achieved by insemination with fresh semen, frozen semen is being used increasingly to overcome logistic problems as well as to minimize disease transmission from infertile donors. The latter is of major importance with increased concern over the possibility of infection of TDI recipients with the AIDS virus. The chances of this can be minimized by banking semen from donors who have tested negative for the HIV antibody, and not releasing it for use until the donor has shown a second negative test a minimum of six months later (Peterson *et al.*, 1988).

Banking of semen by cryopreservation, from individuals scheduled to undergo chemotherapy or radiation therapy, enables a man to father children at a later date even though these therapeutic measures may have produced either temporary or permanent damage to his spermatogenic processes. Similarly, women about to undergo such therapeutic procedures, or who may be otherwise at risk of premature ovarian failure, could bank oocytes for later use after their ovaries were no longer functional.

Recent research has produced promising results with cryopreservation of human embryos (Testart *et al.*, 1987). As a consequence, it is now possible to store excess embryos from a given oocyte collection and IVF attempt, for replacement in the donor at a subsequent cycle if conception has not occurred from the fresh embryos replaced at the treatment cycle. There is evidence to suggest that conception rate might actually be improved by withholding replacement until a subsequent cycle because of detrimental effects on implantation of the hormonal treatment regimens used to induce follicle stimulation for oocyte collection.

Pregnancy results (Figure 1) which we and others have obtained with replacement of varying numbers of embryos immediately after the treatment cycle indicate that, although the chances of pregnancy increase with increasing numbers of embryos replaced, they do not do so in direct proportion to the

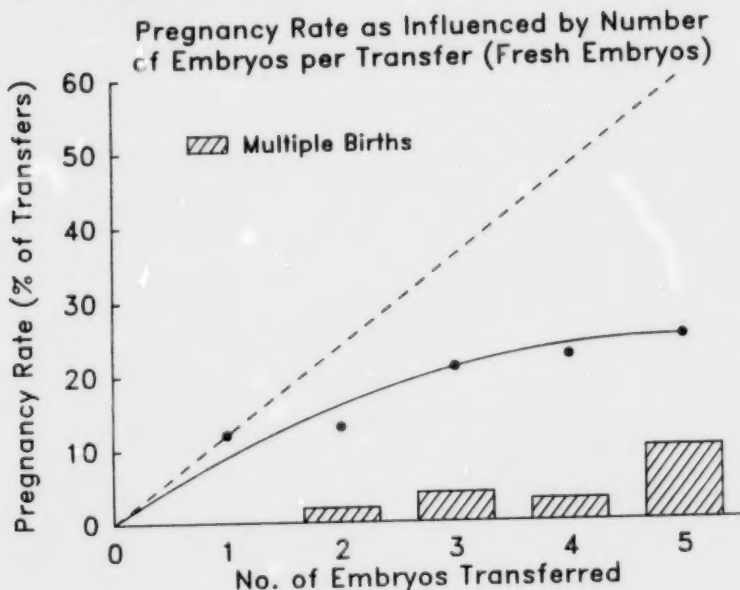


FIGURE 1 Pregnancy rate following in vitro fertilization and replacement of varying numbers of embryos. (—) observed pregnancy rate per transfer; (---) rate extrapolated from initial rate observed with transfer of a single embryo.

number replaced. Therefore, on a *per embryo* basis, the chances of pregnancy decrease as the number of embryos replaced increases above a single embryo. An additional disadvantage of transferring more than one, or at most two embryos, is that the probability of multiple pregnancies, with their inherent increased perinatal risks, increases dramatically. If cryopreservation of embryos can be developed to a degree of efficiency such that no losses occur as a result of freezing and thawing, then the pregnancy rate could be increased substantially in patients yielding multiple embryos, by freezing the embryos for thawing and replacement in subsequent cycles, one embryo per cycle. By extrapolating the "initial rate" of 12% (the pregnancy rate achieved on transfer of a single embryo, Figure 1) to five transfers (one embryo at a time), an overall expected pregnancy rate of 60% would be expected for women yielding five embryos. This estimate compares favourably with the value of 50% recently published by Guzick *et al.* (1987) as the cumulative pregnancy rate achieved by patients undergoing five successive IVF and ER attempts.

Cryopreservation of embryos has other potential applications, including facilitation of embryo biopsy and genetic screening techniques for detection of inherited defects. It may also be used by couples wishing to postpone starting a family, but wanting to minimize chances of age-related genetic defects, by banking embryos produced from gametes obtained when the risks were lower.

Although compelling arguments can be advanced for the cryopreservation of human embryos, as discussed above, the introduction of such a procedure on a widespread scale does raise ethical and legal problems, as discussed in detail recently by Robertson (1981).

APPLICATION OF REPRODUCTIVE TECHNOLOGY NOT RELATED TO INFERTILITY

Genetic Screening

The ability to fertilize human eggs *in vitro* and to maintain the resulting embryos in culture through several cleavage divisions provides the embryologist with a "window" through which to observe early developmental events not previously available for study of the human embryo. This technique, together with the development of highly sensitive probes capable of detecting products of gene activity in a few cells, has enabled genetic analysis of pre-implantation embryos without the necessity of sacrificing the embryos (Monk, 1987). The opportunity is now available, therefore, to take biopsies from embryos grown through the early cleavage stages, and analyze the resulting cells for possible genetic abnormalities, while the viable embryo remains frozen in a state of "suspended animation." With these techniques, which are now available for a limited number of sex-linked and other inherited metabolic diseases, it will be possible to identify embryos that should be "aborted" before they have been implanted. The principle of abortion of fetuses with genetic abnormalities detected by amniocentesis or chorionic villus biopsy is already accepted by a significant segment of society. The ability to detect such abnormalities before the embryo has been replaced and has established a pregnancy should be equally acceptable, ethically, and discard of such embryos before implantation would presumably be easier for couples to accept than abortion once pregnancy had become established.

Gene Therapy

The ability to detect at early pre-implantation stages embryos bearing genetic abnormalities raises an additional option that may soon become available, that of introducing new genes into the pre-implantation embryo to compensate for, or replace, genes detected as abnormal or lacking. The feasibility of production of somatic cell chimeras by bone marrow transplantation in fetuses *in utero*, as a means of correcting deficiencies in hematopoiesis, has already been demonstrated (Wagemaker *et al.*, 1986). The production of chimeras by injection of cells into the blastocoel of pre-implantation blastocysts has also been accomplished. Such "therapy" would probably be of no greater risk than post-implantation therapy, to the embryo, and would be no risk at all to the mother.

Gene replacement at an even earlier stage of development—by micro-injection of cloned β -globin genes into pronuclear stage zygotes formed at fertilization, has been carried out in an experimental animal model of

β -thalassemia (Constantini *et al.*, 1986). The resulting transgenic mice were "cured" of this inherited blood disorder, in that the introduced gene was transmitted through the germ line to their progeny. Although it is clear that transfer of genes into the germ line does not represent an acceptable method for overcoming inherited human diseases, the technique offers a powerful tool for investigation of regulation of these genes during embryogenesis, in animal models of similar diseases.

Cell Transplantation

Recent reports of alleviation of some of the symptoms of Parkinson's disease by transplantation of neural tissue including fetal brain tissue into afflicted patients (Madrazo *et al.*, 1987) raises the possibility of the use of cultured human embryonic cells for similar purposes (Snyder, 1987). The potential for benefit to suffering adults will have to be weighed against the acceptability, on ethical grounds, of using aborted fetal tissue for such purposes. Whether undifferentiated cells grown in culture from human embryos which have never implanted would be less or more acceptable, ethically, will undoubtedly be the subject of considerable debate, should studies with animals prove the efficacy of such treatments.

SUMMARY

The foregoing review has summarized reproductive technologies which have emerged in recent years, designed to treat human infertility resulting from a variety of causes. Sperm-oriented techniques include artificial insemination using semen from donors or partners. New approaches, including deposition of washed spermatozoa directly into the uterine cavity or fallopian tubes, permit conception by men whose sperm numbers are substantially reduced. Egg-oriented techniques, including *in vitro* fertilization, drilling of zonae pellucidae and microinjection of spermatozoa directly beneath the zonae pellucidae, permit fertilization with still lower sperm numbers.

Egg-oriented techniques, including *in vitro* fertilization followed by embryo replacement (IVF-ER), offer hope for infertile women, especially those whose infertility is the result of blocked or absent fallopian tubes, and endometriosis. Modifications of this procedure, involving transfer of gamete or zygote into the fallopian tubes, are often at least as effective as IVF-ER in women with patent fallopian tubes, whose infertility is due to unknown causes.

Several indications for use of emerging reproductive technologies in applications not directly concerned with treatment of human infertility are presented. In particular, techniques are now available for screening pre-implantation embryos for chromosomal abnormalities or genetic deficiencies, enabling embryos conceived by IVF to be "aborted *in vitro*." Techniques are also available for introduction of genes into embryos to replace defective or absent genes, either by direct injection into pronuclei of newly fertilized eggs,

or by production of somatic cell chimeras by cell transplantation into embryos at blastocyst stage. Techniques of embryo culture *in vitro* may provide, in the future, a source of embryonic stem cells available for transplantation into adults for repair of damaged or diseased tissues or organs.²

REFERENCES

- Asch, R.H., Balmaceda, J.P., Ellsworth, L.R., and Wong, P.C. (1986) Preliminary experiences with gamete intrafallopian transfer (GIFT). *Fertil. Steril.* 45:366-71.
- Baer, K.E.v., cited by Betteridge, K.J. (1981) An historical look at embryo transfer. *J. Reprod. Fertil.* 62:1-13.
- Chang, M.C. (1959) Fertilization of rabbit ova in vitro. *Nature* 184:466-67.
- Costantini, F., Choda, K., and Magram, J. (1986) Correction of murine β -thalassemia by gene transfer into the germ line. *Science* 233:1192-94.
- Fevold, H.L., Hisaw, F.L. & Leonard, S.L. (1931) The gonad-stimulating and luteinizing hormones of the anterior lobe of the hypophysis. *Amer. J. Physiol.* 97:291-301.
- Gordon, J.W. and Talansky, B.E. (1986) Assisted fertilization by zona drilling: a mouse model for correction of oligospermia. *J. Exp. Zool.* 239:347-54.
- Guzick, D.S., Wilkes, C., and Jones, H.W. (1986) Cumulative pregnancy rate for in vitro fertilization. *Fertil. Steril.* 46:663-67.
- Heape, W. (1891) Preliminary note on the transplantation and growth of mammalian ova within a uterine foster mother. *Proc. R. Soc.* 48:457-58.
- Hunter, J., cited by Beck, W.W. (1984) Two hundred years of artificial insemination. *Fertil. Steril.* 41:193-95.
- Laws-King, A., Trounson, A., Sathananthan, A.H. and Kola, I. (1987) Fertilization of human oocytes by microinjection of a single spermatozoan under the zona pellucida. *Fertil. Steril.* 48:637-42.
- Leeuwenhoek, A.v., cited by Meyer, A.W. (1939) The rise of embryology. Stanford University Press, p. 138.
- MacCorquodale, D.W., Thayer, S.A. & Doisy, E.A. (1936) The isolation of the principal estrogenic substance of liquor folliculi. *J. Biol. Chem.* 115:435-48.
- Madrazo, I., Druker-Colin, R., Diaz, V., Martinez-Mata, J., Torres, C., and Becerril, J.J. (1987) Open microsurgical autograft of adrenal medulla to the right caudate nucleus in two patients with intractable Parkinson Disease. *New Eng. J. Med.* 316:831-34.
- Mann, J.R. (1988) Full term development of mouse eggs fertilized by a spermatozoan microinjected into the zona pellucida. *Biol. Reprod.* 38:1077-84.
- Monk, M. (1987) Biochemical microassays for x-chromosome-linked enzymes HPRI and PGK. In: *Mammalian Development: a practical approach* (Editor, M. Monk). IRL Press, Oxford, U.K.
- PETERSON, E.P., ALEXANDER, N.J. AND MOGHISSI, K.S. (1988) AID and AIDS—too close for comfort. *Fertil. Steril.* 49:209-10.
- Pincus, G., Rock, J., Garcia, C.-R., Rice-Wray, E., Paniaga, M. and Rodriguez, I. (1958). Fertility control with oral medication. *Am. J. Ob. Gyn.* 75:1333-46.
- Robertson, J.A. (1987) Ethical and legal issues in cryopreservation of human embryos. *Fertil. Steril.* 47:371-81.
- Snyder, S.H. (1987) A cure using brain transplants? *Nature* 326:824-25.

2 I am grateful to Dr. Sue Daniel for providing up-to-date summaries of results from the University Hospital IVF program, and to Mrs. Nancy Wilson for typing of the manuscript. Dr. David T.

- Step toe, P.C. & Edwards, R.G. (1978) Birth after re-implantation of a human embryo. *Lancet* ii:336.
- Testart, J., Lasalle, B., Ferman, R., Gazengel, A., Belaisch-Allart, J., Hazout, A., Rainhorn, J.-D., and Frydman, R. (1987) Factors influencing the success rate of human embryo freezing in an in vitro fertilization and embryo transfer program. *Fertil. Steril.* 48:107-17.
- Wagemaker, G., Visser, T.P. and van Bakkum, D.W. (1986) Cure of murine thalassemia by bone marrow transplantation without eradication of endogenous stem cells. *Transplantation* 42:248-51.
- Wood, C. and Trounson, A. (1984) *Clinical In Vitro Fertilization*. Springer-Verlag, Berlin.

A New Stork Rising? Women's Roles and Reproductive Changes[†]

ANYONE who has not been living in a remote cave will know that reproduction in the past decade has been changing rather dramatically. These changes have occurred on several fronts. Writing as a sociologist, I shall emphasize the social aspects of these changes, looking first at some of the changes in and challenges to reproduction today, and then at some of the social implications of the advent of "high tech" reproduction, including the questions of who controls and who benefits from the new reproductive technologies. Finally, I shall speculate on what the future might hold, in terms of the social implications of changed reproduction.

CHANGES AND CHALLENGES TO REPRODUCTION TODAY

The birth rate in Canada, as in most parts of the Western world, is at an all time low. The Province of Quebec is one of four or five places with the lowest birth rates in the world. Family size has declined precipitately. Large families are now almost extinct, two children being the norm. Recent speculation by the Vanier Institute of the Family holds that Canadians might be moving toward a one-child family as normative (Lodh, 1987). In short, replacement of the Canadian population is no longer guaranteed.

Accompanying declining birth rates have been lower rates of marriage, slight declines in the likelihood of remarrying after divorce (particularly for women), and increased rates of cohabitation. Births outside of marriage have also increased, most dramatically for women aged 30-39 (Dumas, 1987). Child-

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[†] Presented at the symposium, "Why Are Canadians Dying Out?" University of Windsor, 8 June, 1988.

lessness within marriage also seems to be increasing, although whether or not couples are postponing children permanently is not certain.

In the political and policy realm, a number of changes are occurring which could have implications for reproduction in Canada. For example, the Free Trade agreement, according to some studies in Ontario, might have important implications for women's jobs. If two incomes are necessary to maintain children, then there could also be birthrate implications in the agreement. Some feminists in anglophone Canada have been concerned because the Meech Lake Accord does not explicitly protect women's rights, in that access to reproductive control techniques, including abortion, might not be guaranteed. Daycare has been said to be necessary if two-career families are to have children. An initiative toward subsidizing daycare has recently been taken by the federal government. The abortion law struck down by the Supreme Court in early 1988 has not been rewritten. As well, Canada has been undergoing in 1986-89 a Demographic Review, the ultimate consequences of which remain to be seen.

HIGH TECH REPRODUCTION

In Margaret Atwood's *The Handmaid's Tale*, women in the repressive theocracy of Gilead have become reproductive robots as part of the attempt to quell social unrest and women's growing demands for equality, and to raise the declining birth rate. This vision is frightening not because it is so far-fetched, but precisely because it may *not* be. In many ways, Gilead may involve a rather small extension of tendencies and realities well entrenched in Canadian society in the late 1980s, although little known and even less well understood by most Canadians.

Average Canadians, when they think of the new reproductive technologies such as surrogate motherhood, artificial insemination, or *in vitro* (or test-tube) fertilization, tend to think of the happiness brought to childless couples by being able to have their own children. In fact, some *in vitro* couples are not childless, but *have* children of their own (Williams, 1988). The new reproductive technologies seem like a miracle, a baby from science and technology, what might earlier have been called a gift from heaven. Few Canadians think beyond these happy images to what the implications of the new reproductive technologies might be for society, for social relations between women and men, and among women.

Already in the late 1980s doctors can produce test-tube babies, conceived through artificial insemination or carried by surrogate mothers. These techniques are now being franchised in the United States under the venture capital scheme called "Baby U." Sperm from Nobel laureates and Mensa-ranked men can be bought from banks. Embryos can be transferred or frozen, and sex selection techniques can be used in laboratory conception to guarantee that the sex of our offspring is what we wish. Artificial wombs are being

developed, and procedures by which men can be pregnant through the implantation of an embryo in the male abdomen are being researched.

As recently as 1971 Shulamith Firestone argued in a landmark book that women might be set free by reproductive technology. The thinking at that time was that women's reproductive roles, socially defined, tended to limit their opportunities in other realms. Firestone speculated that if reproduction could take place without women's direct involvement, then possibly equality could be attained. Now in the few short years that the new reproductive technologies have become real and available, it is far from clear that they will indeed free women. Growing numbers of critics are expressing grave concerns about what the techniques might mean for women's roles and rights.

What is specifically included in the new reproductive technologies are sex-selection techniques (both pre- and post-conception), various types of artificial insemination (by donor, known as AID; by husband, known as AIH; and by combined semen from donor and husband, known as AIC, and the whole range of "test-tube" techniques including *in vitro* fertilization, embryo replacement, transfer and "flushing," and embryo freezing (Arditti, Klein, and Minden, 1984). Sometimes surrogate motherhood involving artificial insemination by the man who intends to become the legal father is included as well. All these techniques are available and in use now, with varying degrees of accessibility and success. None is governed by law in any clear way in Canada. Looming on the horizon are cloning, artificial placentas (or "glass wombs"), genetic engineering, and the somewhat silly, but perhaps symbolic, prospect of implanting and presumably gestating a fertilized egg in the abdomen of a man.

All these techniques are medical practices that, in varying degrees, are invasive of the female body. All place the control of reproduction somewhere other than with women or couples. All involve the medicalization of reproduction, and the subsequent redefinition of women who cannot reproduce as medically deficient in some way, even if the "problem" is their husbands' and not their own. All, particularly taken together, tend to centre women's roles on reproduction, which we may now be expected to go to great lengths and expense to attain. Perhaps most importantly, all tend to open the possibility that women as childbearers will become obsolete.

There is little doubt that these technologies point to a "brave new world" and yet, when examined more closely, they are not so new, and perhaps not so brave either. For example, it is not new to have the control of reproduction lie elsewhere than with women. What is new in the "new" reproductive technologies is that *parts* rather than the *whole* of women's bodies are used and controlled. As Klein (1985) suggests, women now may be seen as uteruses, ovaries, eggs, and embryos which can all be separated and reassembled so that the parts can work in union (Klein in Corea *et al.*, 1985a:66). Medicalization of reproduction is also not new. Childbirth, for example, was taken out of the hands of the traditional experts—midwives and women themselves—and placed firmly under the control of obstetricians who are highly trained medical

specialists, usually male (Oakley, 1980). Contraception, under the control of women for millenia, has now become mainly a medical procedure, with distinctly mixed consequences, as is well known (Overall, 1987). The "new" reproductive technologies clearly have much in common with some long-established trends and practices.

Many of the seemingly new approaches date back rather a long way. For example, surrogate motherhood is found in the Book of Genesis where Rachel, Jacob's infertile wife, had her maid Hagar bear two children for them. Similarly, the longstanding system of adoption, both public and private, has served as a kind of surrogate motherhood: poor and young women bear children for those who are better off and older (Brodrribb, 1984:2; Ferguson, 1984). The first recorded artificial insemination occurred in 1884 at Jefferson Medical College in Philadelphia, but this technique has been practised since the eighteenth century (Brodrribb, 1984:3). A patient of a Dr. Pancoast was discovered to be infertile because of her husband's lack of sperm. Without the woman's knowledge, the doctor injected sperm provided by one of his medical students into her uterus under anaesthesia, while a group of male medical students watched. She gave birth to a son nine months later. Her husband was apparently informed and was happy about the procedure; the woman herself was never told (Corea, 1985b:12; Achilles, 1986:6).

WHO CONTROLS AND BENEFITS FROM THE NEW REPRODUCTIVE TECHNOLOGIES

The new reproductive technologies are brought to us by medical rescarchers like those who brought us the old anti-reproductive technologies such as the birth control pill, D.E.S., and the Dalkon shield (McDaniel, 1985a). This fact alone is cause for concern, since our experience shows that the best interests of women are not always part of the motivation to develop reproductive control techniques.

More significant and perhaps more terrifying for women than the vested interests of doctors in the new reproductive technologies is the interest of society generally. The new reproductive technologies have not been tested thoroughly with primates (Williams, 1986b), thus it could be argued that women who use them, often at *their* own expense, are "living laboratories, or 'test-tube women'" (Klein, 1985:65). In the case of *in vitro* fertilization, the process is often painful, extremely expensive, and time consuming. The failure rate of *in vitro* fertilization is around 80 per cent (Achilles, 1987:13), a figure not publicized sufficiently. Images of happy couples leaving hospitals with healthy babies fade quickly when one becomes aware of the potential physical and psychological damage to countless women, of experiments with fertility drugs and the repeated use of highly invasive surgery techniques.

What used to be called begetting, siring, procreation, or even genesis of new life has now taken on the terminology of the factory—reproduction is seen as

similar to production (Achilles, 1985:10). The profoundly mysterious and wondrous process of conception, which many philosophers have seen as women's greatest source of creativity, and which has been the source of male envy in many parts of the world, has now been turned into a medical technological riddle solvable by modern science.

A woman submitting to artificial insemination by donor in a medical clinic must relinquish more often than not her right to choose, or even know, who is the biological father of her child. This practice certainly marks a profound shift in reproductive relations between women and men. Similarly, a woman using *in vitro* fertilization must admit that her own or her husband's infertility is a medical problem, to be solved by medical science. New reproductive techniques are seen as "cures" for infertility, thus giving infertility a new status as a medical disorder. This new label perhaps stigmatizes as much as if not more, than the old label of "barren." Royal barren women were sometimes beheaded for their incapacities. One can easily imagine a situation not far removed from that in Atwood's Gilead in which modern infertile women cannot easily choose to remain childless when technology exists to help them "cure" their supposed deviance.

Access to the new reproductive technologies is controlled by doctors, hospital and clinic committees, and, perhaps most importantly in the long run, by legislators. Research by Williams (1986a; 1986b; 1986c) on the admittance criteria of the Ontario *in vitro* fertilization clinics reveals this clearly. For example, doctors deciding what medical conditions make patients appropriate for their technologies, allow only those who have been referred by other doctors, those with certain prespecified medical conditions (women with any fertility problems but malfunctioning fallopian tubes are barred initially from many *in vitro* programs, and women whose husbands have no sperm count are excluded), and, importantly, those under age 37-40, depending on the hospital (Williams, 1986b). Significantly, social criteria are also included in the admittance criteria. For example, only married or stable cohabiting couples are eligible, and so doctors or other professionals must assess the stability of such relations. In some clinics, couples are screened as to how many children they have at home, with priority being given to couples with no naturally-born children. That adopted children, apparently, count less suggests that primacy is given to biological parenthood over social parenthood by the clinics (Williams, 1988).

Recommendations of the 1985 Ontario Law Reform Commission on the control of the new reproductive technologies may reinforce male and medical dominance. The OLRC, for example, emphasized the importance that all forms of artificial insemination be seen as medical procedures controlled and administered by doctors. No means of grievance or appeal should be open to women who are denied "treatment" by the new reproductive technology clinics, according to the OLRC recommendations (OLRC, 1985:275). Artificial insemination and other technological "treatments" are to be confined to married

women or to heterosexual women *with* partners. This recommendation bars access to single women, both heterosexual or lesbian, who are deemed by the Commission to be less suitable for parenthood. Even the term "artificial insemination" or "reproduction," as used by the OLRC, is male-oriented, as is the term "illegitimate child." A child who is born cannot be illegitimate, unless viewed through the lens of male control over reproduction—an illegitimate child is one whose father is not legally married to its mother, the implication being that the woman is not under legally sanctioned male control of her reproduction. Similarly, the term "artificial" insemination suggests that what is natural is what males do, i.e., have intercourse with females, and that if reproduction occurs without such intercourse, it is somehow unnatural or artificial. To the woman experiencing pregnancy and childbirth, it is no less "natural" or "real."

Behind the new reproductive technologies lurks the belief that biological parenthood takes precedence over social parenthood. Basic to the talk of gamete banks in the OLRC report and to the processes by which technology lets us have our *own* children, is an emphasis on the importance of genetic links between parents and children. Women become the means by which genes are given life, as evidenced by legal precedents on surrogate motherhood, the medical practices surrounding the new reproductive technologies, and the emerging legal recommendations about its control. Emphasis is placed not on the joy of parenting, which could be done by childless couples and childless women and men through adoption, fostering, informal care of relatives and friends' children, or even shared parenthood, but rather on *biological* parenting. Infertility, which many experts suggest is on the rise because of environmental pollution, workplace hazards, diet, and way of life (Achilles, 1985:11), is now seen as a medically curable biological deficiency. Consequently infertile women may come to see their infertility as a source of anguish, a life crisis or even an illness. Previously when this occurred, the solution was found in social parenting rather than in a quest for a biological parental role, paramount over all else.

The opening of possibilities for genetic engineering, for "harvesting" only perfect babies out of the many that could be conceived in petri dishes, the selection of only "correct" sperm or ova, or "correct" women as breeders, looms large on the immediate horizon. Clearly, biology and genetics are now being given priority, which will likely increase, while people in "unacceptable" categories such as the handicapped, the single, the poor, the gay or lesbian, or ethnic minorities, may be denied the opportunity to reproduce by these expensive and inaccessible "brave new world" techniques. The prospects are nightmarish indeed.

Questions of male consent underlie the discussion of both artificial insemination and surrogate motherhood. For example, the OLRC recommends that the consent of husbands/partners be obtained for artificial insemination

procedures for fear they be seen as adultery. Fears run high that women might be able to use the new reproductive technologies to procreate without males or to engage in sexual relations not under male control. For example, the Dean of the University of Manitoba Law School has remarked:

if artificial insemination becomes common, it may cause wives to deceive their husbands. A childless wife, after obtaining her husband's consent to resort to artificial insemination, would be able to carry on with impunity sexual intercourse with her lover, secure in the knowledge that she could attribute any pregnancy which might result to artificial insemination. (Quoted in Brodribb, 1984:19.)

In the case of surrogate motherhood, it is generally husbands who contract with the surrogate, not wives. One way to interpret this pattern is that the husband has two wives, like Jacob in Genesis; one can compare it to the system of concubinage, where one "wife" reproduces and the other is for social purposes. Fathers' rights tend to take precedence over mothers'. The term "surrogate," like the term "artificial" when used in relation to reproduction, is in fact father-oriented, based on male consciousness of reproduction and birth. In fact, any women who gestates and gives birth to a baby is its mother, no matter how it is conceived.

Another important aspect of women's roles as reproducers that is affected by the new reproductive technologies is the increased perception of women as reproducers and children as commodities. Women's reproduction has always had market value. In some African societies women's reproductive potential must be tested before her marriage market value can be assessed. There was also a value placed on women in slavery producing slave children. In our own society, rich men can "buy" fertility by marrying young fertile women. The new reproductive technologies mean that fertile women can sell their reproductive capacity. The going rate for a surrogate mother in Canada is around \$10,000 (1986 dollars). Similarly, women might be able to sell ova, or even uteruses, fallopian tubes, or ovaries for transplants in the future. Frozen embryos may come to have a market value, as light-skinned Latin American babies have come to have for those willing to pay high prices to adopt them in the United States, Canada, and Israel.

The prohibitive cost of using the new technologies, in combination with the required screening process, tend to create divisions among women. Poor women who cannot afford access to the new reproductive technologies, or the expense involved in foreign adoptions, or who may be deemed unworthy to adopt a child by the Canadian authorities, may become reconciled to life without children, no matter how strong their desires. Meanwhile poor women might observe other poor women facing sanctions, either formal or informal, against childbearing. A boost might be given to a two-tiered system of childbearing where the rich get every encouragement in their quest for children,

while the poor are not only denied access to reproductive technologies, but are discouraged from having children, generally by welfare systems and social attitudes.

One can imagine a sperm bank of the future in which vials are marked with IQs and the costs increase as the IQs increase. If this seems like science fiction, it should be noted that in California in 1982 the first baby was born from a sperm bank set up for Nobel prize winners, called "The Repository for Germinal Choice."¹ This story took an unexpected turn when it was discovered that the mother of the baby, previously reported to be of high intelligence, was in fact an ex-convict who had lost custody of two children after her husband was accused of child abuse.²

A variation on the theme of quality sperm banks might be a ranking system for aspiring surrogate mothers in which those with higher intelligence, better family backgrounds, better looks, and very likely white skin, were given higher priority as surrogates than other women. Issues of surrogate motherhood as economic opportunity aside, this tendency could result in an increase in the birth rate among certain types of people, with a decrease among others. It is not much of a jump to project a situation where poor women with the socially defined "right" attributes might be coerced economically into becoming virtual reproduction machines for another class.

A very contentious political and social issue emanating from the new reproductive technologies is the identity of the parents of infants born as a result. It is possible to have genetic mothers, birth or "womb" mothers, and social mothers, all different. For example, one woman could supply the ova which when fertilized are implanted in the uterus of a second woman for gestation. A third woman who contracted for the baby then could become the social and legal mother. Similar complexities of course exist for fathers. Given the serious social and legal issues being raised now about adopted children's rights to know about their birth parents, one can foresee social and legal wrangles. On the negative side, women could become splintered into specialty reproductive groups—gene providers, breeders or baby processors, and social mothers—each representing a particular class and political position. There is, however, paradoxically, a positive side. An aspect of the new reproductive technology involves the quest for biological parenthood, for a child of one's own. Yet, the possibilities inherent in the new technologies may force the realization, long important in adoption, that social parenting is ultimately much more important than biological parenting to the child, and also the parents.

A final political issue involved in the new technologies relates to sex-selection techniques. Many ways are being explored and perfected for selecting or detecting the sex of a fetus. Among these are separation of X from Y sperm

1 "Sperm Bank Has First Birth," *Kitchener-Waterloo Record*, 25 May, 1982, p. 19.

2 "Sperm Bank Mom Ex-Con, Spouse Cited in Child Abuse," *ibid.*, 18 July, 1982, p. 47.

prior to conception, diet control, and timing (the latter two once thought to be old wives' tales, now written about in the authoritative *New England Journal of Medicine*), selective abortion after amniocentesis, and implanting only one-sex fetuses after IVF, to name only a few of the many possibilities (Holmes and Hoskins in Corea, *et al.* 1985a:15-20). There are strong motives to predetermine the sex's of one's child. It seem to be a growing part of the process of birth planning, but there is a more insidious aspect. Several prominent people, among them the publisher Clare Booth Luce, have argued that preferential birth of boys will lower the birth rate ultimately since it is females who give birth (cited by Holmes and Hoskins, in Corea, *et al.*, 1985a:21).

Across the world, most people prefer sons to daughters. Sometimes this preference is so strong that females are subject to infanticide. We also know from many studies that the first-born of either sex have distinct advantages. In Third World countries, sons may have access to more and better food. In countries like Canada, sons may be given more parental attention. Further, and this is important for women's future achievements, girls from single-child families or all-girl families tend, on average, to be higher achievers than girls from other kinds of family. Sex-selection techniques and the strong preference for sons may mean that girls will be born far less often than boys and when born, will be born second to the preferred first-born male. Cultural views about women can literally become manifest at birth. Sex-selection techniques make it possible that women would never be born except as needed to continue reproducing the species. These prospects are all the more frightening because they are so real and so close to the present.

IMPLICATIONS FOR THE FUTURE

As we have seen, the new reproductive technologies have broad implications for women, for families, and for society. Motherhood, that seemingly unassailable image often linked with apple pie, is changing in many ways.

The new technologies, particularly when considered together with the old ones, tend to make reproduction and motherhood increasingly public. Standards of acceptable motherhood are agreed upon, as admittance criteria for application of the new technologies are established. These standards differ substantially from those of yore which simply required mating and the desire to have children.

Associated with the establishment of clear standards of acceptable parenthood is a homogenization of motherhood images. All mothers may be expected to have a decent income before they consider motherhood, or no genetic problems, or to be married legally, or not to be lesbians, etc., etc. Whatever the standards become, they are excluding from motherhood many women whose lives do not fit the rules but who, in fact, might be wonderful mothers.

Motherhood, with the new technologies, takes on a mandate. It can become

the reason for women's existence, as women engage in years-long quests for babies of their own. Doctors, legislators, and society generally may interpret such quests (and have done so already) as resulting from a reproductive urge built into women's biologies. Women without children in future may appear, by contrast, to be even stranger than they appear today. As well, women's quests for motherhood may usurp their quests for opportunities in the work place, as energies that might be used to develop careers, or to strive for justice for women, become channelled into the long-term "project" of becoming mothers.

The new reproductive technologies are being marketed to women as a means to increase their choices about childbearing. The irony here is that such choices may actually decrease as more women are pressured into seeing themselves primarily as mothers. The choice of voluntary childlessness, at least for well-off women, is already difficult to make, given the strength of social pressure on women to reproduce. With the new technologies, families, spouses, the media, and society may encourage women even more to fulfil themselves as mothers by "choosing" reproductive technology.

Given the technological desire in western society to push back the frontiers of nature so that it can be controlled, it might be predicted with some certainty that interfering with reproduction and making ever-greater interventions in women's bodies, are not likely to stop, barring social revolution or a massive change in orientation. The potential profits to be reaped through development and marketing of these technologies contributes further to the incentive to pursue them. With cloning, development of glass wombs, possibly reproductive brothels or baby factories, medical control over and usurping of women's reproduction will likely become more complete.

Women's quest for control over their bodies may become an even larger political issue than it is today. As the centre of attention for women shifts from reproductive control to reproductive rights, one can imagine the rallying cry of women shifting from women's rights to access to abortion or contraception, to a woman's right to bear a child on her own terms.

On the bright side, the reproductive technologies, if controlled by women, may have the potential of making women's range of reproductive choices wider. One can imagine an underworld of women who pre-select females babies and encourage all women who wish to have children to have them and to raise them with love and caring. Ultimately, this could make an interesting experiment to see whether social environment or genes prevail in adults' lives, achievements, and happiness. When the evidence is in, it will likely show that a wanted child who grows up in a loving environment does better than all the gene-spliced and Nobel-sperm-banked babies produced by technological "advances." At that juncture, all this technological reproduction may be rejected, as we return to old-fashioned coupling, motherhood, and non-scientific child-bearing.

REFERENCES

- Achilles, Rona. "New Age Procreation," *Healthsharing* 6(4):10-14, 1985.
- "The Social Meanings of Biological Ties: A Study of Participants in Artificial Insemination by Donor," Unpublished Ph.D. thesis, University of Toronto, 1986.
- "Women and Reproductive Technology" in S. Burt, L. Dorney, and L. Code, eds., *Changing Patterns: Women in Canada*. Toronto: McClelland & Stewart, 1988.
- Arditti Ri, Renate Duelli Klein, and Shelley Minden, eds. *Test-Tube Women: What Future Motherhood?* London: Pandora Press, 1984.
- Atwood, Margaret. *The Handmaid's Tale*. Toronto: McClelland and Stewart, 1985.
- Brodrigg, Somer. "Reproductive Technologies, Masculine Dominance and the Canadian State," *Occasional Papers in Social Policy Analysis*, No. 4. Toronto, OISE Press, 1984.
- Corea, Gena, ed. *Man-Made Women: How New Reproductive Technologies Affect Women*. London: Hutchinson, 1985a.
- Corea, Gena. *The Mother Machine: Reproductive Technologies from Artificial Insemination to Artificial Wombs*. Toronto: Fitzhenry and Whiteside, 1985b.
- Dumas, Jean. *Report on the Demographic Situation in Canada, 1986*. Current Demographic Analysis (Cata No. 91-209E Annual). Ottawa: Statistics Canada, 1987.
- Ferguson, Evelyn E. "The Real Cabbage Patch Kids: An Examination of the Canadian Private Adoption System," *Occasional Papers in Social Policy Analysis*, No. 2. Toronto, OISE Press, 1984.
- Firestone, Shulamith. *The Dialectic of Sex: The Case for Feminist Revolution*. London: Jonathan Cape, 1971.
- Holmes, Helen B. and Betty B. Hoskins. "Prenatal and Reconception Sex Choice Technologies: a Path to Femicide?" in Gena Corea, et al., eds. *Man-Made Women: How New Reproductive Technologies Affect Women*, pp. 15-29.,
- Klein, Renate Duelli. "What's 'New' about the 'New' Reproductive Technologies?" in *ibid.*, pp. 64-73.
- Lodh, Françoise. *Explaining Fertility Decline in the West (with special reference to Canada): A Critique of Research Result from Social Sciences*. Ottawa: The Vanier Institute of the Family, 1987.
- Matthews, Anne Martin and Ralph Matthews. "Beyond the Mechanics of Infertility: Perspectives on the Social Psychology of Infertility and Involuntary Childlessness," *Family Relations* 33:479-87, 1986.
- Matthews, Ralph and Anne Martin Matthews. "Infertility and Involuntary Childlessness: The Transition to Non-Parenthood," *Journal of Marriage and the Family* 48:641-49, 1986.
- McDaniel, Susan, A., "Abortion, Reproductive Technology and Women's Roles as the Barter of the New Right." Paper presented at the Ontario Association of Sociology and Anthropology, Waterloo, Ontario, 1985.
- "Women's Roles and Reproduction: The Changing Picture in Canada in the 1980's," *Atlantis*, 1988.
- "Women's Roles, Reproduction and the New Reproductive Technologies: A New Stork Rising," in A. Duffy and N. Mandell, eds. *The Canadian Family: Feminist Perspectives*. Toronto: Butterworths, 1988.
- Oakley, Ann. *Women Confined: Towards a Sociology of Childbirth*. London: Martin-Robertson, 1980.
- Overall, Christine. *Ethics and Human Reproduction: A Feminist Analysis*. Boston: Allen and Unwin, 1987.
- Sandelowski, Margarete. "Sophie's Choice: A Metaphor for Infertility," *Health Care for Women International* 7(6):439-53, 1986.

Veevers, John E. *Childless by Choice*. Toronto: Butterworths, 1980.

Williams, Linda S., "But What Will They Mean for Women? Feminist Concerns about the New Reproductive Technologies," *Feminist Perspectives*, No. 6. Canadian Research Institute for the Advancement of Women, 1986a.

- "Who Qualifies for In-Vitro Fertilization? A Sociological Examination of the Stated Admittance Criteria of Three Ontario IVF Programs." Paper presented at the Canadian Sociology and Anthropology Association meetings, Winnipeg, June 1986b.

- "Wanting Children Badly: The Social Construction of Parenthood Motivation in Women Seeking In Vitro Fertilization." Paper presented at the Second International Congress of Women's Health Issues, Halifax, Nova Scotia, Nov. 1986c.

- "Wanting Children Badly: the Social Constuction of Parenthood Motivation in Women Seeking In Vitro Fertilization." Ph.D. thesis, University of Toronto (Ontario Institute for Studies in Education), 1988.

Abortion, the Foetus and the Supreme Court†

IT MAY BE questioned whether any male, other than the married or common law spouse of a pregnant woman, or her medical practitioner, has any real competence to comment, let alone legislate, on a pregnant woman's right to an abortion, or on her obligation to carry a foetus to term.¹ However, historically, the law on this issue, whether proclaimed by church or legislature, has invariably been enacted by men alone, and even today in this age of feminism men claim an equal right with women in regard to this essentially female problem.²

It should be pointed out at the beginning that, regardless of popular opinion to the contrary, the Supreme Court's *Morgentaler* decision did not deal with the legality or otherwise of abortion as such. It merely held that the provisions of s. 251 of the Criminal Code, rendering a particular surgical process for pregnant women criminal, unless undertaken in the statutory fashion, were contrary to the Charter of Rights and Freedoms and invalid. It may be suggested, therefore, that any comments going beyond this and relating to a right to abort were, strictly speaking, *obiter*. Moreover, some of the comments made by individual judges, though expressed as applying to women, are equally applicable to the citizenry at large, particularly in light of the non-discriminatory provisions in the Charter³ and the Canadian Bill of Rights.⁴ Thus, Mme Justice Wilson

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† Presented at the symposium, "Why Are Canadians Dying Out?" University of Windsor, 8 June, 1988.

1 See e.g., comment by Mme Justice Wilson in *Morgentaler et al. v. The Queen and Att. Gen.*, Canada (1988), ms. judgment, at pp. 14–15 of her judgment.

2 *Paton v. Trustees of the British Pregnancy Advisory Service* (1979) Q.B. 276; *Dehler v. Ottawa Civic Hospital* (1979), 101 D.L.R. (3d) 686. See also, Frankowski, USA, Frankowski and Cole, Abortion and Protection of the Human Foetus. 1987, 17 at 38–41.

3 Constitution Act 1982, s. 15 (1).

4 1960, 8–9 Eliz. II, c.44, s.1.

stated:

an aspect of the respect for human dignity on which the Charter is founded is the right to make fundamental personal decisions without interference from the state. This right is a critical component of the right to liberty. Liberty, . . . properly construed, grants the individual a degree of autonomy in making decisions of fundamental personal importance. . . . Liberty in a free and democratic society does not require the state to approve the personal decisions made by its citizens; it does, however, require the state to respect them. . . . [T]he right to liberty contained in s. 7 [of the Charter] guarantees to every individual a degree of personal autonomy over important decisions intimately affecting their private lives. . . . [T]he right to "security of the person" under s. 7 protects both the physical and psychological integrity of the individual. State enforced medical or surgical treatment [is] an obvious invasion of physical integrity. . . . [T]he present legislative scheme for the obtaining of an abortion clearly subjects pregnant women to considerable emotional stress as well as unnecessary physical risk. . . . In essence, what it does is assert that the woman's capacity to reproduce is not to be subject to her own control. It is to be subject to the control of the state.⁵

It takes but little amendment of these remarks to make them applicable to almost any patient seeking any type of medical treatment or even wishing to indulge in self-mutilation or destruction. Under this type of reasoning it would be easy to conclude that the common law rules holding a suicide *felo de se*,⁶ the current law on euthanasia *in extremis*,⁷ or the old common law rules on maiming which, regardless of the desires of the individual, condemned as criminal the removal of even a finger, let alone a deformed or withered limb, or castration,⁸ would all be considered as contrary to the Charter of Rights. It is difficult to deny that any state interference in any of these directions interferes with "the right to make fundamental personal decisions" and subjects the individual seeking such treatment to limits on his "personal autonomy over important decisions affecting his private life."

There is little to be gained from analyzing each of the judgments. It suffices to refer to the general principles underlying the views of the majority for it is this which constitutes the law. Before doing so, however, it is necessary to comment upon s. 251 of the Code and the various provisions of the Charter considered relevant. By s. 251 procuring the miscarriage of a pregnant woman is only legal if done by a qualified medical practitioner performing the act in

5 At pp. 7-8, 13, 26 of her judgment; see, also Dickson C.J. at pp. 15-16 of his.

6 Blackstone, *Commentaries on the Laws of England*, Bk. IV, ch. 14, 10th ed., 1787, 189.

7 See, e.g., Grisez and Boyle, *Life and Death with Liberty and Justice*, 1979; Heifetz and Mangel, *The Right to Die*, 1975; St. John-Stewas, *The Right to life*, 1964; and Williams, *The Sanctity of Life and the Criminal Law*, 1957. See also Netherlands proposal to legislate a defence for doctors practising euthanasia—a defence somewhat akin to s. 251, *The Globe and Mail*, 26 Apr. 1988.

8 Blackstone, *op. cit.*, 205-6 (the reason he gives is that mayhem renders the individual less potent, and so "less able in fighting either to defend himself or to annoy his adversary").

good faith in an approved or accredited hospital, provided the act has been approved by a therapeutic abortion committee of this hospital comprising no fewer than three members, excluding the practitioner in question. The committee must certify that continuance of the pregnancy "would or would be likely to endanger the woman's life or health." It should be noted here that ever since the English decision in *R. v. Bourne*,⁹ it has been accepted in Anglo-American law that the concept of "health" for this purpose includes mental as well as physical well-being. Moreover, the World Health Organization defines health "not merely as the absence of disease or infirmity, but as a state of physical, mental and social well-being"¹⁰ indicating that there exists a duty upon the medical profession to consider the "holistic" welfare of the patient.

The principal sections of the Charter which are relevant are 1, 2(a), 7 and 15. By s. 1, the rights guaranteed by the Charter are "subject only to such reasonable limits prescribed by law as can be demonstrably justified in a free and democratic society." This is not the place to argue that, since Canada is a democracy with a government and parliament freely and democratically elected, every measure passed by the Canadian parliament is "demonstrably justified in a free and democratic society." Such a contention would mean the negation of the entire Charter at the whim of Parliament. But in assessing what is "reasonably justifiable" in such a society, it would be proper for the court to refer, as was done in the *Rauca* case,¹¹ to the practice of other democracies. In fact, Beetz J. did mention a variety of foreign enactments embodying somewhat similar provisions to those in s. 251.¹² However, neither he nor any of his colleagues seemed to consider these relevant in assessing the significance of s. 1. Instead, the majority appears to have been satisfied with the reasoning of the United States Supreme Court in *Roe v. Wade*,¹³ regardless of the differences in the culture and ethical approaches of the two countries,¹⁴ and the fact that *Wade* turned on the right to privacy, not an issue in *Morgentaler*.

Perhaps more important, for much of the language of the Charter appears to have been based on it, is the European Convention on Human Rights. It repeatedly refers to limitations "prescribed by law and necessary in a democratic society."¹⁵ Further, s. 7 of the Charter reflect the Convention's

9 [1939] 1 K.B. 694, see also *R. v. Newton* [1958] Crim. L.R. 469 (C.C.A. re sentence, *The Times*, 15 Oct. 1958—the accused was convicted of manslaughter).

10 Per Dickson, C.J. at p.30., see W.H.O. Constitution, 1948, Preamble.

11 *Germany v. Rauca* (1982) 38 O.R. (2d) 705, 141 D.L.R. (3d) 412, re compatibility of extradition with s. 6(1).

12 See pp. 41–42, 60–61 of his judgment. See eg. Frankowski and Cole, *Abortion and Protection of the Human Foetus*, 1987.

13 410 U.S. 113, (1973), dealing with a woman's right to privacy and abortion during the three trimesters of her pregnancy.

14 See Re B.C. Motor Vehicle Act [1985] 2 S.C.R. 486, per Lamer J. at 498: "We would in my view do our own Constitution a disservice to simply allow the American debate to influence the issues for us, all the while ignoring the truly fundamental structural differences between the two constitutions" cited with approval by Dickson C.J. at p. 11.

15 1950, 213 UNTS 222, see, eg., Arts 8,9,10 and 11.

language, for its guarantees that "everyone has the right to life, liberty and security of the person and the right not to be deprived thereof except in accordance with the principles of fundamental justice." Article 5 of the convention provides to "everyone the right to liberty and security of person. No one shall be deprived of his liberty save . . . in accordance with a procedure prescribed by law," and, without any further mention of "security," proceeds to indicate that this right is intimately connected with the legal process. Similarly the International Covenant on Political and Civil Rights¹⁶ to which Canada is a party refers to "security of the person" in the same context. Moreover, the Charter provision is the first in that part of the document which deals with "legal rights," the remainder of which, ss. 8-14, are concerned with the criminal process, making no further reference to "security of the person." The majority of the judges seem to have torn this concept completely out of context giving it an interpretation that appears to have comparatively little to do with the legal process as such, even if it be conceded that the conditions on which a miscarriage may be procured are regarded as part of the criminal process providing a defence to what would otherwise be a criminal act.

The majority tended to accept the views of Mme Justice Wilson in an earlier non-related case¹⁷ that "life, liberty, and security of the person" are independent interests, each of which must be given independent significance by the Court.¹⁸ The Chief Justice pointed out that the Charter elevates security of the person to

the status of a constitutional norm. . . . State interference with bodily integrity and serious state-imposed psychological stress, at least in the criminal law context, constitutes a breach of security of the person. It is not necessary in this case to determine whether the right extends further, to protect either interests central to personal autonomy, such as a right of privacy, or interests unrelated to criminal justice. . . . [S.] 251 of the Criminal Code is *prima facie* a violation of the security of the person of thousands of Canadian women who have made the difficult decision that they do not wish to continue with a pregnancy. At the most basic physical and emotional level, every pregnant woman is told by the section that she cannot submit to a generally safe medical procedure that might be of clear benefit to her unless she meets criteria entirely unrelated to her own priorities and aspirations. Not only does the removal of decision-making power threaten women in a physical sense; the indecision of knowing whether an abortion will be granted inflicts emotional stress. S. 251 clearly interferes with a woman's bodily integrity in both a physical and emotional sense. Forcing a woman, by threat of criminal sanction, to carry a foetus to term unless she meets certain criteria unrelated to her own priorities and aspirations, is a profound interference with a woman's body and thus a violation of security of the person. S. 251, therefore, is

16 1966, 999 UNTS 171—Canada became a party 19 May 1976.

17 *Singh v. Minister of Employment and Immigration* [1985] 1 S.C.R. 177, 204-5, approved in *Re B.C. Motor Vehicle Act*, n. 14 above at 500.

18 Per Dickson C.J. at p. 11.

required by the Charter to comport with the principles of fundamental justice. . . . The evidence indicates that S. 251 causes a certain amount of delay for women who are successful in meeting its criteria. In the context of abortion, any unnecessary delay can have profound consequences on the woman's physical and emotional well-being.¹⁹

Beetz J., too, made similar comments, and all pointed out that the delay varied from province to province, while in some parts of Canada there were either no hospitals accredited for the performance of abortions, or hospital committees had failed to permit the establishment of the abortion committee envisaged by s. 251.²⁰

As a result of these different practices, the Chief Justice and Beetz J.²¹ concluded that "fundamental justice" was not done, since the law was operating in an unequal and inequitable fashion, in some cases, resulting in a situation in which a woman and her doctor might in fact find themselves denied the defence provided in the legislation.²² Moreover, such circumstances mean that the right to equality before and under the law and the right to the equal protection and equal benefit of the law guaranteed by s. 15 of the Charter are infringed, and Dickson C.J. expressly rejected the "saving" suggestion that a pregnant woman might travel to some other area where a legal abortion under s. 251 might be possible.²³ This raises the question whether it would infringe the guarantee of equality if a pregnant woman living as a hermit had some 200 miles or more to travel to reach a maternity hospital. And what of the disproportionate distribution of geriatric doctors, or institutions competent to perform heart transplants throughout the country, or the inability of small or cottage hospitals to secure accreditation as teaching institutions?

Abortion is hotly debated as a matter of both conscience and of religious belief. Does this warrant measuring s. 251 against s. 2 of the Charter guaranteeing "freedom of conscience and religion" as one of the "fundamental freedoms [enjoyed by] everyone"? *Prima facie*, the combination of religion and conscience suggests some necessity of a belief in faith or rationalism, a view which finds support in Article 18 of the International Covenant, proclaiming that "everyone shall have the right to freedom of thought, conscience and religion. This right shall include freedom to have or adopt a religion or belief of his choice, and freedom . . . to manifest his religion or belief in worship, observance, practice and teaching." The same wording is used in the European Convention,²⁴ with both instruments having their origin in the Universal Declaration of Human Rights, whose sole reference to "conscience" is in relation to religion.²⁵

¹⁹ At pp. 12, 15-16.

²⁰ Dickson C.J. at pp. 17 et seqq., Beetz J. at pp. 13 et seqq.

²¹ At pp. 21 et seqq.

²² Dickson C.J. at p. 32.

²³ At pp. 33-34.

²⁴ Art. 9.

²⁵ 1948, Gen. Ass. Res. 271 (III) A, Art. 18; Canada voted in favour.

The Supreme Court has given the concept of "conscience" an extremely wide connotation as may be seen in the *Big M Drug* judgment:

What unites enunciated freedoms in . . . s. 2(a) of the Charter and in the provisions of other human rights documents in which they are associated is the notion of the centrality of individual conscience and the inappropriateness of governmental intervention to compel or constrain its manifestation. . . . The values that underlie our political and philosophic traditions demand that every individual be free to hold and to manifest whatever beliefs and opinions his or her conscience dictates, provided inter alia only that such manifestations do not injure his or her neighbours or their parallel rights to hold and manifest beliefs and opinions of their own. Religious beliefs and practice are historically prototypical and, in many ways, paradigmatic of conscientiously-held beliefs and manifestations and are therefore protected by the Charter. Equally protected, and for the same reasons, are expressions and manifestations of religious non-belief. . . . I leave to another case the degree, if any, to which the government may, to achieve a vital interest or objective, engage in coercive action which s. 2(a) might otherwise prohibit. . . .²⁶

The *Morgentaler* case provided the opportunity for Mme Justice Wilson to examine this problem. In her view these comments did not mean

that a personal morality which is not founded in religion is outside the protection of s.2(a). Certainly, . . . conscientious beliefs which are not religiously motivated are equally protected by freedom of conscience in s. 2(a). . . . I am not unmindful of the fact that the Charter opens with an affirmation that "Canada is founded upon principles that recognize the supremacy of God." But I am also mindful that the values entrenched in the Charter are those which characterize a free and democratic society. . . . In a free and democratic society "freedom of conscience and religion" should be broadly construed to extend to conscientiously held beliefs, whether grounded in religion or in a secular morality. . . . For the state to take sides on the issue of abortion, . . . by making it a criminal offence for the woman to exercise one of her options, is not only to endorse, but also to enforce, on pain of a further loss of liberty through actual imprisonment, one conscientiously-held view at the expense of another. It is to deny freedom of conscience to some, to treat them as means to an end, to deprive them . . . of their "essential humanity." Can this comport with fundamental justice? . . . Legislation which violates freedom of conscience in this manner cannot . . . be in accordance with the principles of justice within the meaning of s.7.²⁷

While the learned justice may be correct in her assertion that, "as a matter of statutory interpretation, 'conscience' and 'religion' should not be treated as tautologous if capable of independent, although related meaning,"²⁸ it is submitted that she has in fact ignored the context in which the terms have been used, giving them an unrelated rather than a related meaning. She may even be

26 *R. v. Big M Drug Mart* [1985] 1 S.C.R. 295, 345-47, per Dickson F.J.

27 At pp. 21-22, 23-24.

28 At p. 23.

right in her view

that the decision whether or not to terminate a pregnancy is essentially a moral decision, a matter of conscience The question is whose conscience? Is the conscience of the woman to be paramount or the conscience of the state? I believe that in a free and democratic society it must be the conscience of the individual. Indeed, s.2(a) makes it clear that this freedom belongs to "everyone" i.e., to each of us individually.²⁹

With respect, this sounds more like a prescription for anarchy than a commitment to the maintenance of a "free and democratic society."

Interestingly enough, neither Mme Justice Wilson nor Beetz J. thought it necessary to consider whether the concept of "everyone" included the unborn foetus—a view rejected by the common law and the Family Division of the English High Court and the European Commission of Human Rights in the *Paton* case.³⁰ Nevertheless, both confirmed their belief that the primary purpose of s. 251 was preservation of the foetus.³¹ In the view of Beetz J., however, the means employed to achieve this was disproportionate to the interests of the woman and led him to conclude that it was "the decision of the Canadian Parliament . . . that the life or health of the pregnant woman takes precedence over the state interest in the foetus"³²—perhaps a strange view when measured against the idea of 'priority'. Mme Justice Wilson affirmed that

s. 1 of the Charter authorizes reasonable limits to be put upon the woman's right having regard to the fact of the developing foetus within her body. The question is at what point in the pregnancy does the protection of the foetus become such a pressing and substantial concern as to outweigh the fundamental right of the woman to decide whether or not to carry the foetus to term? At what point does the state's interest in the protection of the foetus become "compelling" and justify state intervention in what is otherwise a matter of purely personal and private concern? . . . [C]onsistent with the view taken by the United States Supreme Court in *Roe v. Wade*, the value to be placed on the foetus as potential life is directly related to the stage of its development during gestation. The undeveloped foetus starts out as a newly fertilized ovum; the fully developed foetus emerges ultimately as an infant. A developmental progression takes place in between these two extremes and . . . this progression has a direct bearing on the value of the foetus as potential life. . . . This is not, of course, to deny that the foetus is potential life from the moment of conception. . . . It is simply to say that in balancing the state's interest in the protection of the foetus as potential life under s. 1 of the Charter against the right of the woman under s. 7 greater weight should be given to the state's interest in the later stages of pregnancy than in the earlier. . . . A developmental view of the foetus . . . supports a permissive approach to abortion in the early stages of pregnancy and a restrictive approach in the later stages. In the early stages the woman's autonomy would be

²⁹ At pp. 19–20.

³⁰ *Paton v. Trustees of the British Pregnancy Advisory Service* [1979] Q.B. 276; *Paton v. U.K.* (1980) 1 H.R.L.J. 242.

³¹ Wilson at p. 25, Beetz at p. 54, of their respective judgments.

³² At p. 59.

absolute; her decision, reached in consultation with her physician, not to carry the foetus to term would be conclusive. The state would have no business enquiring her reasons. Her reasons for having an abortion would, however, be the proper subject of inquiry at the later stages of her pregnancy when the state's compelling interest in the protection of the foetus would justify it in prescribing conditions.³³

Rather than fully explaining why state interest in the pregnant woman's reasons become so significant, Mme Justice Wilson states that "the precise point in the development of the foetus at which the state's interest in its protection becomes 'compelling' I leave to the informed judgment of the legislature . . ." It might well be considered that this "informed judgment" was the basis of s. 251.

The very question left open by the Court may have to be considered before any new legislation is enacted, for an appeal is pending from the judgment in the Borowski case,³⁴ which turns on the fundamental question of when life begins, it being contended that this is at conception, a factor hinted at by Mme Justice Wilson. Without considering whether a decision on this matter should have taken precedence, it might be pointed out that if the Supreme Court answers this question affirmatively³⁵ it will not revive s. 251. Rather, it will mean that any destruction of a fertilized ovum, whether *in utero* or *in vitro*, will amount to the unlawful killing of a living being, and, since it is done intentionally, to murder. On the other hand, since the aborted foetus would be dead there could no longer be any moral grounds of opposing the use of tissues therefrom for any medical purpose—unless it be argued that the corpse of a homicide should never be utilized in this way.

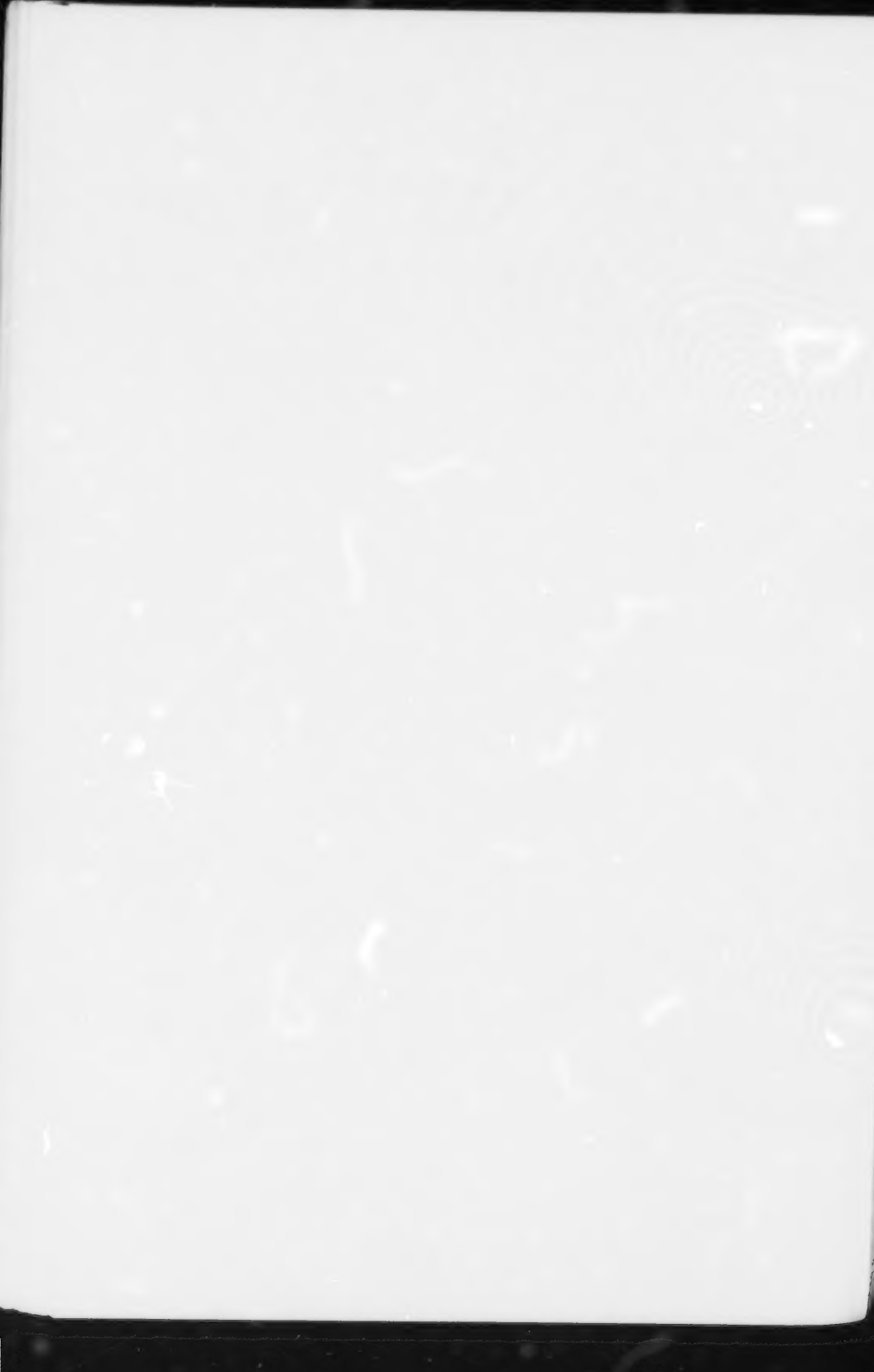
There is no need to comment upon the joint dissent of McIntyre and La Forest JJ., for it is the majority who have declared the present state of the law. While these comments are highly critical or the majority view, this is not because the author favours legislative restrictions upon the right of abortion, at least not before the twenty-fourth or twenty-sixth week, for like Mme Justice Wilson he regards the whole issue as one of a private medical character between the woman and her doctor, and perhaps her spouse. His unease lies in the feeling that the majority have allowed personal feelings with regard to the right to abortion to outweigh their proper function as judicial interpreters. While they have been willing to overrule Parliament on what may be regarded as extensive and activist grounds, they have nevertheless conceded that a woman's right to abortion, which the minority holds to be non-existent under the Charter, is subject to control by the legislature on somewhat unstated grounds. Logically, it might appear that, given their reasoning, the majority ought to deny any right to life to the unborn foetus and should hold any parliamentary limitation on a woman's right to the security and integrity of her person to be contrary to the Charter and invalid.

³³ At pp. 26–28.

³⁴ *Borowski v. Att. Gen., Canada, and Minister of Finance, Canada* (1983) 8 C.C.C. (3d) 392.

³⁵ The Supreme Court in 1989 refused to find on this in the absence of any abortion legislation.

**Award Winner /
Laureat Médaille**



A Funny Thing Happened on the Way to Serendip[†]

FIRST LET ME say how honoured I am to have been selected for the Thomas W. Eadie Medal of the Royal Society of Canada. I can only hope that the work my group and I have done, and are doing, will someday contribute to human welfare in the field of medicine as extensively as did Thomas Eadie's contribution in the field of communication.

What I would like to describe is how a seemingly trivial technicality opened our eyes to an interesting biological phenomenon that would otherwise certainly have been missed. To tell you about it I shall have to go back a bit.

Some years ago (more years than I care to count in fact), we made what was to us a startling observation. That was that a single gene could decide whether a mouse would or would not develop leukemia if infected with a certain virus. The virus was known as Friend Virus after Dr. Charlotte Friend, who first isolated it. In mice that carried the gene for susceptibility, a small dose of the virus would induce rampant disease within a few days. Mice that carried the gene for resistance were protected indefinitely against even large doses of the virus. We were very excited. But on perusing the literature we learned that we'd had the honour of being confirmed in advance, as the man said. A Japanese group had made the same observation three years before us. Well in any case, we thought, it would be interesting to find out how a gene confers resistance against a leukemia virus.

So we set out on a selective mouse breeding program and after three-and-a-half years Henk Van der Gaag and I had produced a pair of mouse strains that were almost like identical twins except that they differed by part of one

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[†] Presented to Academy III, at the Annual Meeting of the Royal Society of Canada, University of Windsor, 5-8 June, 1988. (For the story of the word 'serendip', see Remer, T.G. (ed.), *Serendipity and the Three Princes from the Peregrinaggio of 1557* (Norman: University of Oklahoma Press, 1965).

chromosome which carried the critical gene. One mouse strain had the gene for susceptibility; the other had the gene for resistance to Friend Leukemia Virus. Otherwise they were almost alike.

The next thing that happened was this: Dr. Shigetoh Suzuki, a postdoctoral student, made the interesting observation that in those mice that were genetically susceptible, certain cells were actively synthesizing DNA in preparation for cell division; in those mice that were genetically resistant to the virus, the same cells were not synthesizing DNA. They appeared to be lying dormant. And this difference had shown up in the complete absence of infection with the virus. It was the normal state for these mice. We began to suspect that it was these cells that were turned leukemic after infection with Friend Virus. Perhaps the fact that they were already synthesizing DNA made the cells susceptible to the virus, and the fact that the cells in the other strain were not synthesizing DNA made them resistant.

This experiment had been done with the cells still inside the intact animals. To study the phenomenon under better control, Dr. Suzuki tried to take the cells out of the body into cell culture. but when he did this, a strange thing happened. The dormant cells immediately became active and began synthesizing DNA. Cells from the two mouse strains now behaved in the same way, so the difference between them could no longer be investigated, and Dr. Suzuki returned to Tokyo without having found out the basis for this peculiar growth behaviour.

My technician Denise Eskinazi then repeated the experiment that Dr. Suzuki had done. But she got the opposite result! The cells taken out of the mice continued to behave as if they were still inside them. That is, the cells taken from the virus susceptible strain were synthesizing DNA in culture, and the cells from the virus resistant strain were not.

Denise was asked to describe to us step-by-step what she had done, while the rest of us compared this with what Shigetoh had done. All at once a student and I both shouted "Where's the centrifugation step?" and she said "What centrifugation step?"

You see, Shigetoh had been trained in Japan where cells taken from the body were considered to be dirty and had to be washed before any experiment could be done with them. Washing actually amounted to centrifuging the cells down to a pellet and then resuspending the cells in fresh medium. Denise had been trained in France where cells taken directly from the animals were not considered dirty, and were centrifuged only if a higher concentration of them was needed. What one did was simply centrifuge them and resuspend the pellet in a smaller volume of medium. Then the cell concentration would be higher.

I asked Denise to repeat the experiment with and without the centrifugation step. And there it was: the washed cells were found to be synthesizing DNA; the unwashed cells were not. It was as if washing removed something from the outside of the cells that had been keeping them from synthesizing DNA. When Dr. Hélène Croizat, Denise, and I added back the wash water to cells that were

synthesizing DNA, their DNA synthesis was immediately turned off. What's more, it could be turned on again by washing. We were then able to show that the inhibitory activity in the wash water was due to a protein, which we named NRP for Negative Regulatory Protein.

NRP acts specifically on those cells which, when they mature, will become red blood cells. It was the washing of bone marrow cells outside the body that allowed us to find this protein, but we believe that NRP is a physiological molecule which the mouse normally uses to inhibit production of red blood cells when there is no great demand for them. In an emergency situation like a hemorrhage, we know that production of NRP stops. This we think releases the brake, permitting an outpouring of new precursors of red cells to replace those lost.

We also have evidence that normally NRP is made in the marrow during the day but not at night. Had we done our experiments in the middle of the night instead of in the morning, we probably never would have seen the phenomenon of negative regulation of DNA synthesis.

We have spent the past several years trying to purify NRP. As a result of the recent work of a postdoctoral student, Dr. Fred Pluthero, we now have what appear to be the first homogeneously pure samples of NRP; after we obtain its amino acid sequence we plan to go after the gene that codes for this protein. Once we have the gene cloned, we will be able to do many things with it. Among these will be a direct test of the hypothesis that it is the NRP gene itself (and not another gene nearby) that makes otherwise susceptible mice solidly resistant to the development of leukemia after infection with Friend Virus.

In summary, we set out to investigate how a gene confers resistance to a leukemia virus. Along the way we found what we were not looking for, a protein (NRP) that reversibly stops the progenitors of red blood cells from synthesizing their DNA. Physiologically, the protein seems to act as a negative regulator, produced when there is no great demand for red cells and exerting its effect by inhibiting proliferation of red cell progenitors. Present investigations are directed toward finding out whether it is NRP that mediates genetic resistance to Friend leukemia virus, by preventing DNA synthesis in the cells that the virus invades.

REFERENCES

- Axelrad, A.A. Genetic control of susceptibility to Friend leukemia virus in mice. Studies with the spleen focus assay method. Natl. Cancer Inst. Monograph No. 22, pp. 619-29, 1966.
- Axelrad, A.A., McLeod, D.L., Shreeve, M.M. and Heath, D.S. Properties of cells that produce erythrocytic colonies in vitro. In: Hemopoiesis in Culture, Second International Workshop. W.A. Robinson (ed) Airlie House, Va. pp. 226-37, 1973.
- Suzuki, S. and Axelrad, A.A. *Fv-2* locus controls the proportion of erythropoietic progenitor cells (BFU-E) synthesizing DNA in normal mice. Cell 19: 225-36, 1980.
- Axelrad, A.A., Croizat, H. and Eskinazi, D. A washable macromolecule from *Fv-2*^{rr}

marrow negatively regulates DNA synthesis in erythropoietic progenitor cells BFU-E. *Cell* 26: 233-44, 1981.

Axelrad, A.A., Croizat, H., Del Rizzo, D., Eskinazi, D., Pezzutti, G., Stewart, S. and Van der Gaag, H. Properties of a protein NRP that negatively regulates DNA synthesis of the early erythropoietic progenitor cells BFU-E. In: *The Inhibitors of Hematopoiesis*. A. Najman, M. Guigon et al (eds) Paris, John Libby Eurotext. Colloque INSERM 162: 79-92, 1987.

Del Rizzo, D.F., Eskinazi, D. and Axelrad, A.A. Negative regulation of DNA synthesis in early erythropoietic progenitor cells (BFU-E) by a protein purified from the medium of C57BL/6 mouse marrow cells. *Proc. Natl. Acad. Sci., USA* 85:4320-24, 1988.

**Biographical Sketches of
Deceased Fellows
Notices nécrologiques des
membres décédés**



T.P. SCHAEFER, F.R.S.C.*

Alan Newton Campbell

1899–1987



THE DEATH on 10 November, 1987, of Alan Newton Campbell, Professor Emeritus at the University of Manitoba, ended his long and fruitful career as an educator and research chemist. Professor Campbell represented the last link with the beginnings of the Department of Chemistry at that university; his head of department at one time was Matthew Parker, who founded the department in 1904 when he was its sole member.

Alan Campbell was born in Halifax, Yorkshire, on 29 October, 1989. His elementary education in Scotland was followed by B.Sc. (1921) and Ph.D. (1924) degrees from London University and a D.Sc. (1929) from Aberdeen University. He lectured on physical chemistry at Aberdeen from 1925 to 1930, when he joined the Department of Chemistry at University of Manitoba, where he was Head of Department from 1945 to 1966 and Professor Emeritus from 1969 until his death. His intense activity in chemistry began with his first degree, earned by evening study at Birkbeck College, London, and did not end until his death sixty-six years later. His last scientific paper appeared in 1986.

In 1930 the University of Manitoba was essentially an undergraduate teaching institution. In spite of the substantial teaching hours and lack of money, the latter exacerbated by the depression, Alan Campbell would not be deterred from research. Now, when a few grams of a chemical compound may cost eighty dollars, it is perhaps difficult to understand how that amount could launch a Canadian research career. Yet Campbell launched it with that sum, at first in collaboration with his wife, Jean, who also had a doctorate in chemistry. His research on phase equilibria, of great importance in industry, was pursued vigorously over the years and was recognized by his election to the Royal Society of Canada in 1940. In 1951 he and N.O. Smith reworked A. Findlay's book, *The Phase Rule and Its Applications*, for publication by Dover. After World War II, his research interests branched out to include electrochemistry, again a subject of practical importance. The results of all these investigations were reported in over 230 publications. Perhaps just as significant, Alan Campbell's laboratory provided opportunities, rare in the early years, to students intent on chemical research. About eighty students were introduced to and trained in research over the years; a large proportion of them went on to do significant and influential work in governmental, industrial and university laboratories.

Alan Campbell presided as head of the Department of Chemistry during the crucial years from 1945 to 1966. The influx of veterans after the war, the introduction of an honours program for undergraduates and a doctoral program for graduates, the rapid expansion caused by the soaring of Sputnik in 1957, the construction of the Parker Building in 1960, and the doubling of the teaching staff, all occurred during that critical period. In addition, he found time to serve two terms as a member of the National Research Council in Ottawa at a time when the latter was increasing substantially the funds for research at the universities.

As an educator Alan Campbell was concerned that his students develop broad interests, and not only in other areas of science. He himself read widely in history and literature and was a good violinist, having taken instruction at the Guildhall School of Music. At his insistence, for many years the honours program in chemistry at the University of Manitoba required a course in the history of chemistry, which he taught with wit and panache; woe to the insouciant student who achieved an A in calculus but only a C in the history.

The educational work of Alan Campbell was recognized by an LLD from the University of Manitoba in 1982, by the rare election as Honorary Fellow of the Chemical Institute of Canada, and by its Chemical Education Award to him in 1971. On his eightieth birthday, celebrated by his former students and his colleagues, the Department of Chemistry established the A.N. Campbell Scholarship Fund.

Dr. Campbell could exercise great charm; he could be acerbic, particularly with careless undergraduates or with the pompous; he could be kind and often was; best of all, he was never a bore—a real blessing in academia.

Alan Campbell is survived by his wife, Jean, his daughter, Dr. Morag Van Tongerlo, and her husband, Robert, and by two grandchildren, Adrienne and Graeme.

ANTONINE MAILLET, S.R.C.

Clément Cormier
1910-1987



MÉMOIRES DE LA SOCIÉTÉ ROYALE DU CANADA / CINQUIÈME SÉRIE / TOME III / 1988



LES SEULS qui ont le droit de parler en toute liberté et sérénité de la mort sont ceux qui ont aimé passionnément la vie. Les amis du Père Clément Cormier, C.S.C., C.C., peuvent donc parler sans tristesse et sans amertume de sa disparition, parce qu'ils ont appris à son contact que la plus belle des vies est celle qui accomplit son destin jusqu'au bout, jusqu'à ce dernier instant qui donne du sens à tous les autres. La vie du Père Cormier fut un tel chef-d'oeuvre, que sa mort ne nous laisse pas abattus, mais éblouis devant tant de splendeurs. L'Acadie est consciente qu'avec lui elle a vécu son heure étoilée, et qu'une étoile ne meurt pas de sitôt.

Il est difficile de trouver un être qui reflète autant que le Père Cormier l'homme universel et l'incarnation de tout un peuple. Peut-être Don Quichotte. Mais le héros espagnol naissait de l'imaginaire d'un poète, tandis que notre héros acadien est sorti tout vivant des entrailles de sa mère : d'une mère portant les noms très acadiens de Léontine Breau ; d'un père dont l'ancêtre Thomas à Robert, constructeur de bateaux, sortait de La Rochelle sous Louis XIII ; d'une ville, Moncton, qui traîne ironiquement le nom d'un bourreau de 1755 ; d'une date, 1910, à l'heure même où l'Acadie cherchait sa voie, son souffle, se demandant à chaque respiration si celle-là ne serait pas la dernière. Le Père Cormier est né de l'Acadie toute entière, presque avec le siècle, parce que le siècle et l'Acadie avaient besoin de lui.

En 1910, nous étions tous réduits à pleurer nos oignons d'Egypte, nous remémorant avec nostalgie cette belle histoire, épique, tragique, héroï-comique à force d'avoir été passée au bleu de la légende. Nous avions grand hâte de replanter nos arbres et nos piquets de clôture dans la vie quotidienne, et de tourner nos yeux vers le soleil levant. Disons que nous attendions le Messie. Mais les messies n'ont jamais l'allure qu'on leur prête, ne disent pas toujours les paroles qu'on veut entendre. Et pourtant, petit à petit, ils finissent par changer l'orientation des vents et le cours de eaux.

C'est ainsi qu'en cette fin de siècle, quand nous nous retournons pour voir où en est rendue l'Acadie, nous restons ébahis : elle a fait le saut dans les temps modernes. En si peu de temps, nous l'avons vue passer de l'Acadie de la Dispersion à l'Acadie nouvelle. Une naissance qui s'est faite quasiment sans douleurs, en catimini, à la mode acadienne, sans élever la voix et sur la pointe des pieds.

C'était la manière du Père Cormier.

Cet homme appelé à un si haut destin, reconnu comme l'une des grandes figures de son temps, a réalisé son oeuvre sans faire de tapage inutile, sans partir en guerre. Il a accepté de franchir une à une les étapes nécessaires à la réalisation de son projet. Instinctivement, il s'est mis du bord de son destin.

Après une enfance à Moncton, il fait ses études classiques au Collège Saint-Joseph de Memramcook, berceau d'Acadie, poursuit en théologie à Montréal, puis à l'Université Laval en sciences sociales, économiques, et politiques. En somme, il apprend son métier de meneur d'hommes et de maître à penser de sa génération. Le jour où il deviendra préfet des études, puis recteur

de l'Université de Moncton, personne ne s'en étonnera. Car il ne fit jamais avec bruit et fracas. Curieusement, cet homme que l'on trouve de l'autre côté du mur, n'a jamais défoncé de portes. Les éclats n'étaient pas dans son style.

Pas un loup mais un renard.

Voilà en quoi il fut si profondément acadien. Plus que tous les chefs de file qui l'ont précédé au pays, le Père Clément Cormier a compris qu'un certain temps, un espace limité et peu de moyens lui étaient offerts pour bâtir un monde avec sa vie. Pour ce, il a accepté de refaire du neuf avec des défaisures. Il n'a pas, au nom du progrès, méprisé la mémoire du passé ; non plus que cherché à figer ce passé pour ne pas le laisser se ternir. Il a appelé le pays à se dépasser, à partir à l'aventure sans peur, sans honte, en emportant dans son voyage vers l'avenir le meilleur de son héritage et ses plus sûres valeurs traditionnelles.

C'est ainsi que nous retrouvons le Père Cormier au carrefour de tous les projets sociaux, politiques, ou culturels de son temps. Nous l'avons vu durant cinquante ans enseigner la philosophie et les sciences sociales ; fonder et diriger une université ; présider l'Association canadienne d'éducation de langue française ; fonder la Société historique acadienne ; participer à l'enquête royale sur le bilinguisme et le biculturalisme au Canada ; présider l'Association des universités et des collèges du Canada ; participer à la Commission des droits de l'homme ; fonder la Compagnie des Cent-Associés Francophones ; flirter avec la généalogie, les traditions populaires, la société héraldique du Canada, le Festival d'Art dramatique et les musées d'art ou de traditions. Rien ne lui était indifférent de ce qui pouvait arracher l'homme à sa médiocrité.

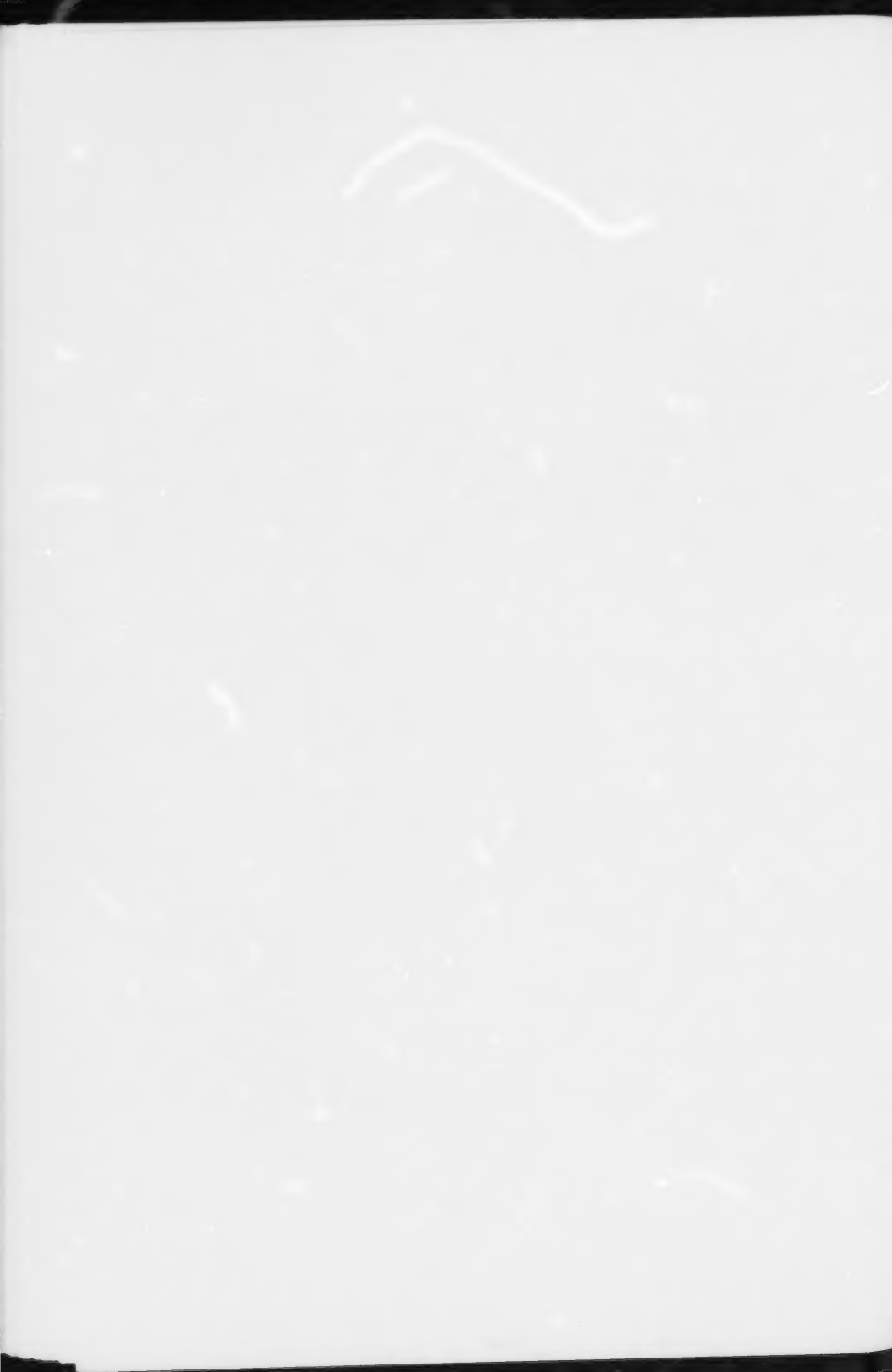
Parce qu'il avait un tel goût de vivre, un tel besoin de grandir, une telle urgence intérieure d'atteindre les sommets, il nous a tous entraînés dans sa course et nous a finalement arrachés à notre complexe de déportés. Comme Socrate par sa maïeutique s'est fait accoucheur de vérité, le Père Clément Cormier a mis au monde une société qui n'osait plus s'appeler par son nom.

Aujourd'hui nous savons que son nom est Acadie, que son étoile s'est rallumée au firmament de l'histoire, grâce à un homme venu naître au bon moment, au bon endroit, et qui n'a pas refusé sa mission.

GUY BEAULNE, S.R.C.

Jan Doat
1910-1988





L'ÉLECTION de Jan Doat à la Société royale du Canada fut pour lui l'occasion d'une grande joie et d'une vive fierté. C'était le témoignage d'accueil d'une seconde patrie à laquelle il avait consacré plus de vingt années de sa vie d'homme et de sa carrière professionnelle.

Il était venu de France à Montréal en 1953, à l'invitation des Festivals de Montréal, pour assurer la mise en scène de *Jeanne au bûcher* de Claudel-Honegger qu'il venait de monter pour l'Opéra de Paris. Wilfrid Pelletier dirigeait les représentations au Palais du Commerce de la rue Berri. Il fut à ce point impressionné par le talent de Jan Doat qu'il proposa aussitôt au premier ministre Duplessis d'en faire son directeur des études dramatiques au Conservatoire de musique et d'art dramatique du Québec qu'il avait fondé en 1942.

Doat avait alors quarante-trois ans. Catholique, il était marié et père de cinq enfants. Son contrat à Montréal était d'une durée de trois ans. Ces trois années, il les vécut intensément et on le vit partout, à la scène, à la radio, à la télévision et au théâtre. Conférencier, enseignant, animateur, critique, conseiller, rien ne le rebute. Il demeure, partout et pour tous, disponible avec enthousiasme. Le théâtre, c'est sa vie.

La mise en scène a été l'axe et la constante de sa vie professionnelle. Profondément engagé dans notre évolution culturelle, il déclarait, dans son discours de réception : « Le voici né ce théâtre, adulte, bien en vie. Mais, outre le talent, les compétences techniques, les moyens matériels, il faut au Québec une *politique de théâtre*, j'entends une politique de théâtre sans politique. »

À Paris, sa formation avait été partagée entre la Faculté de droit et l'école de Charles Dullin, à l'Atelier. Il avait travaillé aussi sous la direction de Jacques Copeau au Théâtre du Vieux-Colombier. Au cinéma, il fut l'assistant d'Abel Gance, réalisa lui-même trois films et enseigna à l'Institut des hautes études cinématographiques. À la Radiodiffusion française il mit en ondes plus de cinquante émissions théâtrales et littéraires. Il avait fondé le mouvement d'action théâtrale, Feux Tournants, pour regrouper le jeune théâtre français et avait créé à cette fin le Théâtre Mouffetard de Paris. Enfin, il avait été conférencier de l'Alliance française.

Après un bref retour en France, en quittant le Conservatoire, il reviendra au Québec pour s'y installer jusqu'à sa retraite.

Gratien Gélinas en fera l'animateur de son Club des spectateurs à la Comédie-Canadienne et son associé à la direction artistique. Il sera critique théâtral à Radio-Canada, et le prestige acquis dans la métropole le désignera comme directeur artistique au Pavillon de la France à l'Expo 1967. Par la suite, il sera professeur au Département des littératures de l'université Laval dont il deviendra le directeur des études théâtrales.

C'est le 10 mai 1975 qu'il est accueilli à l'Académie des lettres et des sciences humaines à la Société royale du Canada, lors de la cérémonie qui eut lieu au Grand Théâtre de Québec, sous la présidence de Richard Arès, s.j., où Maurice Lebel, de l'université Laval, prononcera l'éloge : « Votre don de vie,

qui tient autant de votre tempérament que de votre philosophie de l'existence, vous le faites partager généreusement à votre milieu. Votre bonheur et votre mérite, vous les devez aux trésors de la vie que vous savez répandre autour de vous. »

Il fut un fidèle compagnon et artiste en même temps qu'un praticien au sens le plus total du terme. Sa curiosité insatiable l'a amené à explorer tous les arcanes de notre art. Il nous laisse une douzaine d'ouvrages dont ses cahiers de poésie et de réflexion, ses essais sur le théâtre, une anthologie du théâtre québécois (1606-1970) et une anthologie littéraire de la Bible. Il a bien servi le théâtre, le Québec et la France. Il était Commandeur des arts et des lettres du Gouvernement français et Officier de la Légion d'honneur.

Né à Paris en 1910, il est décédé à Trévou, en Bretagne, le 4 février 1988.

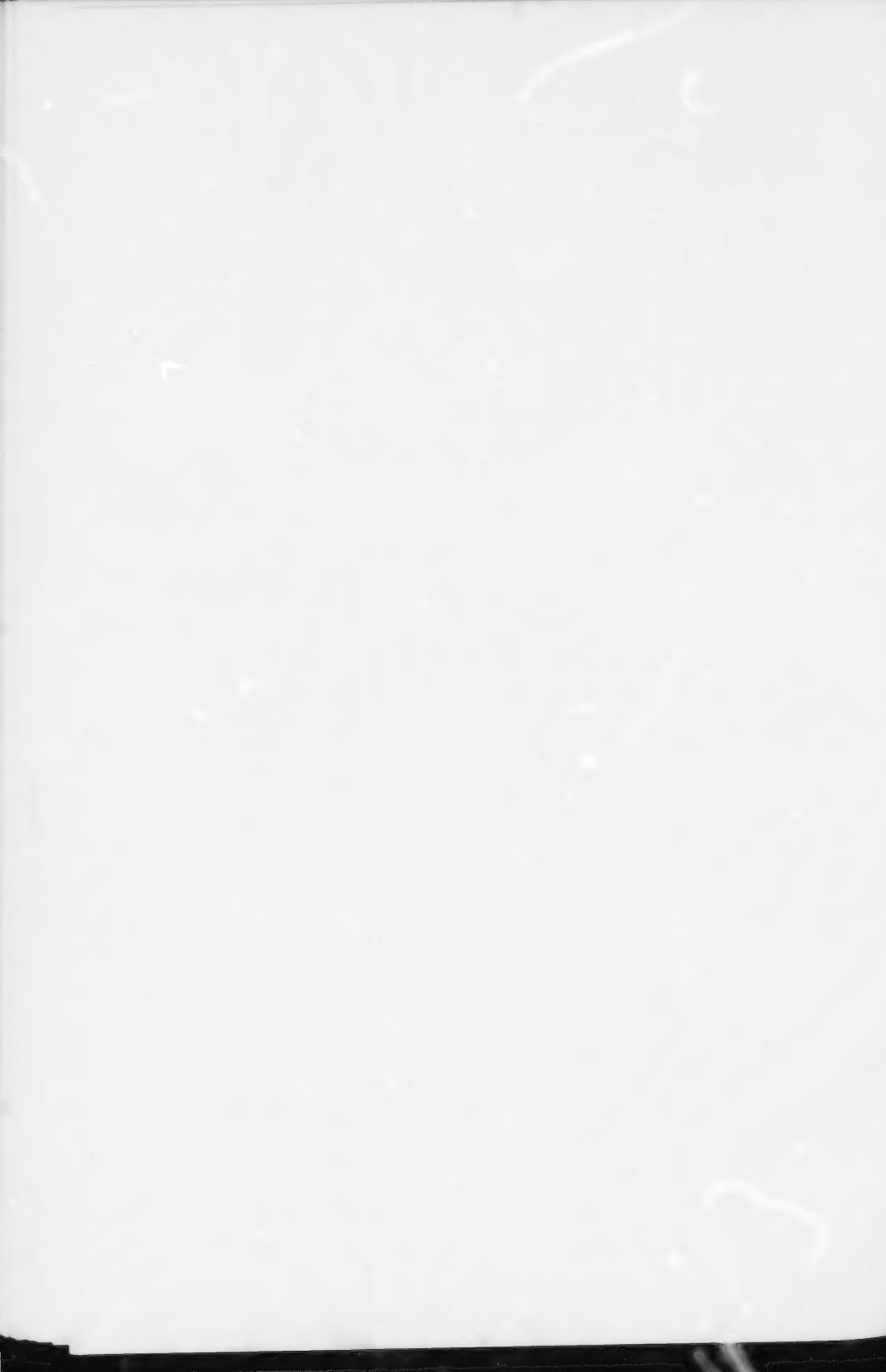
DONALD W. CLARKE & CLAUDE T. BISSELL, F.R.S.C.

Reginald Evan Haist

1910-1987



TRANSACTIONS OF THE ROYAL SOCIETY OF CANADA / SERIES V / VOLUME III / 1988



REGINALD EVAN HAIST, Professor Emeritus of the Department of Physiology at the University of Toronto, died on 15 June, 1987. He is survived by his wife, Margaret, and five children, Lynda, David, Stephen, Margaret, and Frances, as well as his sister, Myra.

Dr. Haist was born in Hamilton, Ontario, in 1910, and his early schooling was in that city. He attended the University of Toronto, obtaining a B.A. 1933 in Biological and Medical Sciences, an M.D. in 1936, and an M.A. in 1937. He obtained his Ph.D. in 1940, and was elected a Fellow of the Royal Society of Canada in 1957. His academic life was spent at the University of Toronto, where he was appointed Chairman of the Department of Physiology in 1965, a post he held until he retired in 1975.

In considering the contributions made by Reg Haist, one is immediately struck with the realization that they were made in a variety of areas, scientific and non-scientific, both nationally and locally.

His scientific work was concerned mainly with certain aspects of diabetes, and he had stated that his greatest ambition was to find the secret of diabetes so that there might be a more satisfying treatment than merely supplementary or replacement therapy. In particular, he made extensive studies on those factors which affected the function of the insulin-producing beta cells of the Islets of Langerhans in the pancreas. Factors which affected islet volume, as well as studies on the synthesis and secretion of insulin from isolated islets, were investigated. While his major and continuing interest had been problems related to diabetes, he and his co-workers also investigated factors influencing the exocrine pancreas, especially the role of the pituitary gland and other endocrine organs.

With a number of different colleagues, Dr. Haist studied the effect a shock resulting from certain types of injury, especially with respect to the metabolism of some substances concerned with carbohydrate metabolism.

Not only did Dr. Haist pursue scientific excellence, but he also served the scientific community with distinction. During his term as president of the Canadian Physiological Society, the Canadian Federation of Biological Societies was formed. He chaired the meetings of representatives of various national societies interested in affiliating with the Canadian Physiological Society. Through these meetings a constitution was prepared and in 1957 at the twenty-first annual meeting of the Canadian Physiological Society, held jointly with the Canadian Society of Anatomists, agreement concerning federation and acceptance of the constitution as a working arrangement was achieved.

He also played a major role in University life. As well as being a strong member of the University Wide Committee which eventually recommended the present form of governance of the University of Toronto, he was asked by Dr. Claude T. Bissell, the President of the University, to chair an Advisory Committee which was to submit recommendations concerning academic appointments, political candidacy, and academic tenure.

The recommendations submitted by this committee were passed with some

modification by the President's Council and have served as guidelines in these areas for staff and administration. The impact of Dr. Haist's work in this regard cannot be over-estimated. He served with distinction two terms as a Departmental Chairman, and was a member of countless committees and sub-committees of the University. The separate remarks of Dr. C. Bissell (see below) further indicate the importance of Dr. Haist's role in the life of the University.

Dr. Haist had a life-long interest in painting, but the demands of University work prevented him from doing as much as he wished. Upon retirement, however, he embarked on a second, and highly successful, career as an artist. He loved to work in watercolours, and most of his paintings were of plants and flowers. He developed a unique, meticulous technique and style, and held several exhibitions. His last, held at the Arts & Letters Club of Toronto during May 1987, was one of the most successful of the various exhibitions held by that club, and he was most pleased at the public response.

In addition to his gifts as a scientist, a teacher, and an artist, Dr. Haist was a man of integrity and honesty, with a keen intellect and a probing mind. Warm and generous, he enjoyed dealing with people, and he and his wife regularly entertained their many friends. It is indeed sad to record the passing of one who was not only an excellent scientist and a gifted artist, but a humane person as well.

D.W.C.

Until the middle sixties, the University of Toronto had not officially consolidated its procedures for making academic appointments and for award of tenure. Appointments were made within departments and on the authority of the Head, who normally conferred with his senior colleague. Tenure was not an active problem, as it was in most American universities. An appointment to a department, at the level of Lecturer and above, meant that the appointee would automatically have tenure, in the sense that he could expect to proceed through the various levels at a pace determined by his own abilities, with promotions originating with the Head of the Department, and confirmed by the Dean of the Faculty in his budget proposals to the President. It became increasingly apparent in the sixties, with the great growth in staff and the complications of the multi-university, that the old informal procedure could not continue. All these matters—appointments (including appointments of 'Heads,' now to be known as 'Chairman,' as well as Deans), the granting of tenure, arrangements for staff members serving in political office—required a formal structure. The formal structure had to be precise and unambiguous in specific recommendations, without losing the informality and the sense of trust that had characterized the life of the university. In November 1964, I set up a committee to recommend new procedures. I realized that this would have extraordinary importance, that it would determine the future of the university in many basic

ways. I needed a Chairman who was a senior scholar, whose interests crossed faculty boundaries, and who was known throughout the university as a man of careful judgment, scrupulous fairness, and generosity of spirit. The man I needed was Reg Haist. He accepted the heavy burden of the chairmanship of the committee on academic appointments, political candidacy, and academic tenure. His committee, consisting of twelve of the senior professors in the university, drawn from all the major faculties, produced the basic academic document of the new era. It was done expeditiously, and it was written with care and precision. It is universally known as 'The Haist Report,' in acknowledgment of the outstanding leadership of its Chairman.

C.T.B.

GEORGE FORD

Robert MacDonald Hardy
1906–1985



ROBERT M. HARDY, an outstanding member of the Canadian engineering community and past Dean of the Faculty of Engineering at the University of Alberta, died Wednesday, 2 October, 1985 at the age of seventy-nine.

Born and educated in Winnipeg, Manitoba, he graduated in 1929 as the Gold Medalist in Civil Engineering from the University of Manitoba. The following year he was awarded the John Bensell Porter Scholarship at McGill University, where he obtained his Master's Degree, specializing in Structural Design. He then joined the Faculty of Engineering at the University of Alberta as a Sessional Lecturer in September 1930.

Economic conditions in the 1930s were difficult, work outside the University was hard to find, and he turned to land surveying. He retained his Dominion, Alberta, and Saskatchewan land surveyor certificates for many years after his career progressed and he had given up surveying. He spent the summers of 1933 and 1934 at the University of Michigan, taking courses related to Applied Mechanics and Structures from Professor S.P. Timoshenko. The first fifteen years of his career were devoted to teaching and consulting in solid mechanics and structures. In 1938 his friend and senior colleague, Professor I.F. Morrison, interested him in the newly emerging field of soil mechanics. In 1939-40 he took his only sabbatical leave to attend the graduate program in soil mechanics and foundations engineering at Harvard University. The pressures that arose due to World War II prevented him from completing his PH.D. but Hardy and his advisor, Professor Arthur Cassegrande, became fast friends, and for over forty years they worked together on a great many assignments.

In anticipation of hostilities, he joined the reserve army, and by 1941 had achieved the rank of Captain. At that time, he transferred to the RCAF as Commanding Officer of No. 8 University of Alberta Squadron, with the rank of Squadron Leader. During the first three summers of the war he acted as a structural consultant to the Defence Industries and to the Aluminum Company of Canada. By 1943 there was sufficient work in Canada to keep a geotechnical engineer busy, and his second career was established.

In 1946 he was appointed Professor, Dean of the Faculty, and Head of the Department of Civil Engineering. His administrative ability saw the Faculty through the trying years immediately following the war, when large numbers of veterans returned to the University. Without question, one of his finest contributions was his handling of the veterans. He took great pains to help those experiencing emotional and academic problems. Many of the graduate veterans acknowledged that, without his personal advice and stimulation, they would have abandoned their university careers.

In May 1959 Dr. Hardy resigned to devote full time to his ever expanding consulting practice, but he retained a part-time research professorship until September 1963 when he was reappointed Dean, a position he held until his retirement in 1971.

While Head of the Department of Civil Engineering, Dr. Hardy instituted the

first graduate program in the field of geotechnical engineering in Canada. His reputation as a teacher, researcher, and practitioner in the field of soil mechanics and foundations attracted students from every province in Canada and from many countries abroad. His former students serve as staff members of at least fifteen universities on this continent and many others are operating their consulting firms throughout the world.

The Canadian Accreditation Board, formed in 1969, drew on his vast experience in setting out the criteria required of every engineering program in Canada. His close contact with his profession, and with industry, gave him a leading role in defining the educational requirements necessary for a sound background for professional practice.

Bob Hardy served his profession throughout his career, first as a member of Council, and in 1950 as President, of the Association of Professional Engineers, Geologists, and Geophysicists. He was elected as the association representative to the Canadian Council of Professional Engineers, serving as President during the 1952-53 term. He held membership in and served on the councils of many technical societies.

Dr. Hardy believed that it is essential for an educator in a professional faculty to participate actively in the practice of that profession. In this area he was eminently successful. He was able to apply the results of his research to the solution of the many and varied problems brought before him. The resulting substantial savings on major construction projects established his international reputation.

In 1958, his recognized achievements in the resource development of Canada led to his appointment to the Borden Royal Commission on Energy, which dealt with National Policies concerning the export of natural gas and markets for Canadian crude oil. The following year he was appointed technical advisor to the Manning Royal Commission on the location of the Pine Point Railway.

His national and international reputation as an educator, researcher, and engineering consultant has been recognized many times in many ways. In 1957 the University of Manitoba, in recognition of his work in initiating and developing geotechnical engineering in Canada, conferred on him the honorary degree of Doctor of Science. He received a Doctor of Science degree from the Royal Military College in 1972. He was elected a Fellow of the Royal Society of Canada, a Fellow of the Engineering Institute of Canada, and a Life Member of the American Society of Civil Engineers and of the Association of Professional Engineers, Geologists, and Geophysicists of Alberta. He received the Keefer Medal from the Engineering Institute of Canada, the Centennial Medal of Canada, the Centennial Award of APEGGA, the R.F. Leggett Award of the Canadian Geotechnical Society, and the Canadian Council of Professional Engineers Gold Medal for 1973. In 1974 he was named an Officer of the Order of Canada and, as well, was the recipient of the Government of Alberta

Achievement Award. In recognition of his distinguished achievements in teaching, research, and the practice of engineering, in 1977, the University of Alberta awarded him an honorary Doctor of Laws degree. In 1978 the Engineering Institute of Canada awarded him the Julian C. Smith Medal.

Through his academic work of teaching, research, and administration, and his public and professional service, he was a busy man. Yet he remained a warm, friendly person who always had time for students and colleagues.

Dr. Hardy is survived by his wife, the former Françoise de Savoye, and by three sons, Stephen of Vancouver, Tony of Victoria, and Alex of Edmonton.

A.J. MOORADIAN, F.R.S.C.

Wilfrid Bennett Lewis
1908–1987





WILFRID BENNETT LEWIS, who was responsible for the scientific direction of the Canadian nuclear program from 1946 to 1973, died at Deep River on 10 January, 1987.

Dr. Lewis was born at Castle Carrock in Cumberland, England, on 24 June, 1908. His father was a civil engineer and at first Lewis, too, wanted to be an engineer, but by the time he entered Cambridge he had chosen to become a physicist.

He arrived with quite unusual electronics expertise, developed from boyhood experiments in a laboratory at his home. He applied this expertise in this research at the Cavendish Laboratory first, starting in 1930, to the properties of alpha particles—ranges and energies—next to the construction of the Cambridge cyclotron, and finally to the study of nuclear reactions and induced radioactivity. Much of this work was carried out in co-operation with Dr. J.D. Cockcroft.

In 1939, with the outbreak of war, Lewis was seconded to the Telecommunications Research Establishment—a deliberate misnomer for the organization that carried out research and development on radar for the Air Ministry. By 1945 he was Chief Superintendent of the TRE, now located at Malvern. Recognition of his contributions from this period included election to Fellowship in the Royal Society of London (1945), appointment as Commander of the Order of the British Empire (1946), and award of the American Medal of Freedom with Silver Palms (1947).

Dr. Lewis came to Canada in 1946 to take over as Director of NRC's Division of Atomic Energy Research at Chalk River from Cockcroft, who had been recalled to the UK. Lewis tackled his new scientific and management challenges with typical zest, recruiting excellent staff and expanding the laboratories. A voracious reader, he was soon thoroughly familiar with all aspects of the work at Chalk River and his detailed knowledge of physics, chemistry, metallurgy, and biology allowed him not only to direct but also to inspire projects.

The contribution to science and technology for which Dr. Lewis is best known, and for which he will be longest remembered, was associated with his key role in the development of a unique Canadian nuclear power reactor system, CANDU. In retrospect, it seems unlikely that this undertaking could have been successfully concluded without his outstanding contribution. When Atomic Energy of Canada Limited (AECL) was formed in 1952, Dr. Lewis was appointed Vice-President, Research and Development. From this position, and the later position of Senior Vice-President, Science, to which he rose in 1963, Dr. Lewis initiated and quarterbacked the drive for nuclear power in Canada via a distinctively Canadian system. His total commitment, involvement, and dedication to this objective inspired and motivated the large group of scientists, engineers and administrators, both within AECL and outside it, that such a large program required to realize this great Canadian achievement.

In the conceptual stage of the program, Dr. Lewis was at the centre of all the major reactor physics and nuclear engineering discussions, providing his own

ideas and analyzing the ideas of others. His well-established capacity for hard work (he carried home two briefcases every night) and his catholic technical interests and capabilities proved invaluable in establishing the basic concept. He not only assimilated the details of all proposals, drawing them into a coherent whole, but in doing so exhibited an uncanny ability to anticipate the principles that time has proved to be of key importance, such as neutron economy and on-power refuelling.

Throughout the program, R&D was required in many diverse fields such as reactor physics, fuel engineering, material behaviour, and radiation chemistry. Dr. Lewis maintained a personal interest in, and direct contact with, every element of R&D, providing suggestions, criticism and encouragement that served to keep all the pieces of the puzzle on course and well focused, as well as demonstrating to the participants the importance of their work.

In the period 1955–1962, the program incorporated the detailed design and construction of a demonstration nuclear power reactor, NPD, at Rolphton, Ontario. While not an engineer, Dr. Lewis became heavily involved in this area also. Through his chairmanship of the NPD Technical Committee, he retained essential control over the project and, at the same time, provided the vehicle for the effective inter-disciplinary, inter-organizational communication that was vital to success. Even after NPD became operational in 1962, Dr. Lewis acted as a senior consultant and advisor in the application of the technology to the prototype and fully commercial nuclear power units that followed.

The culmination of the vision of a viable Canadian nuclear power system came with the successful commercialization of the concept in the Pickering Nuclear Generating Station in 1971. On his retirement from AECL in 1973, Dr. Lewis could look back on a job well done: commercial nuclear power had been launched in Canada on the basis of a distinctive Canadian concept.

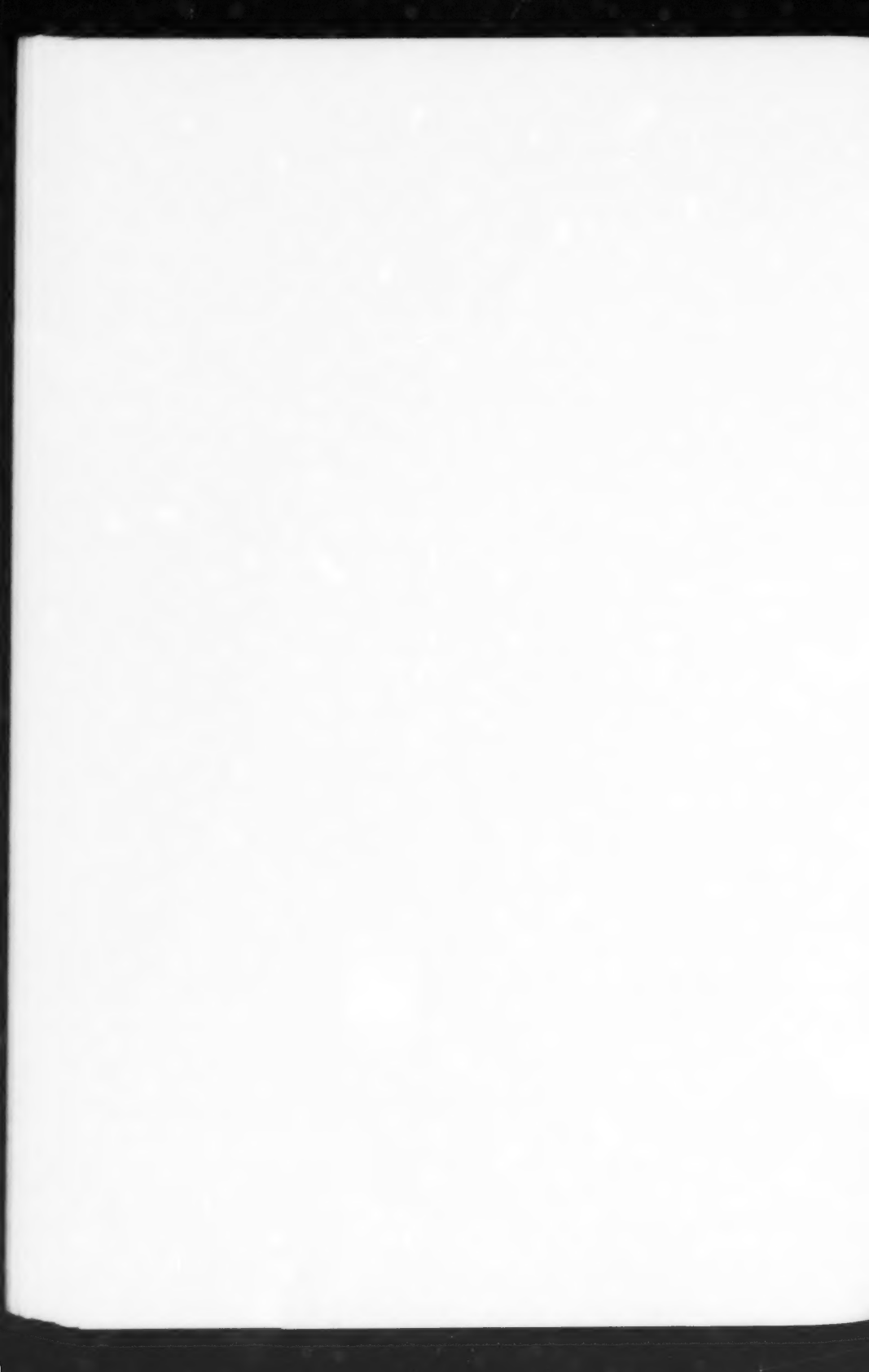
During all this period, he gave invaluable support to a wide range of scientific activities that constituted the "underlying" research base of the nuclear program. One of the most prominent was "pure" nuclear physics research, and he played an important role in ensuring that Chalk River's accelerator facilities were second to none. In the first instance, this led to the High Voltage Engineering Company of Burlington, Massachusetts, developing the first tandem accelerator for Chalk River. When HVEC subsequently developed large tandems, Lewis saw to it that, with the purchase of an MP tandem, CRNL did not fall behind.

Given this strong base, the laboratory was capable of responding effectively to the challenges raised by new ideas, particularly those from Lewis himself. Notable among these was his recognition in 1952 of the importance of the high yield of neutrons from the bombardment of heavy elements by high energy protons and the consequent possibility of "electronuclear breeding," along with the possibility of generating very intense neutron fluxes. The latter idea culminated in the multi-million dollar ING proposal which, to Lewis' great disappointment, was turned down by the government as too expensive.

Following his retirement from AECL in 1973, he became a Distinguished Professor of Science at Queen's University and continued to write and lecture on nuclear energy. He also remained active in international scientific organizations until failing health forced his complete retirement in 1982.

Dr. Lewis was one of the few who can embrace concepts as large as humanity and civilization. Those who worked with him knew a man of enormous breadth, with a tremendous capacity for hard work, an insatiable appetite for knowledge and an outstanding talent for synthesis. He himself claimed that he was not so much an originator as a synthesizer.

(NOTE: Contributions to this obituary have been made by E. Critoph, G.C. Hanna, J.C.D. Milton, and J.D. Hepburn.)



CHRISTIAN BAY, F.R.S.C.

Crawford Brough Macpherson

1911-1987



TRANSACTIONS OF THE ROYAL SOCIETY OF CANADA / SERIES V / VOLUME III / 1988

KNOWN TO THE WORLD as C.B. Macpherson, he was known to his friends as Brough. He died 21 July, 1987, at the age of seventy-five. His death is a heavy loss to his family, his friends, and his university, and also to his profession, his country, and indeed to the world.

Macpherson was the most widely translated and probably the most profoundly influential of Canadian social and political scientists. What is more important than the extent of his fame is that his influence will remain, strongly humanist and critical of much of the conventional wisdom in our society, inside and outside the academic world.

He was born in Toronto on 18 November, 1911. His parents were both teachers, and there were two sons and one daughter in the family. Brough became an achiever as a youngster, being admitted to the excellent University of Toronto Schools. After undergraduate years at the University of Toronto, he went to the London School of Economics, University of London, where in 1935 he earned his M.Sc. in economics. Twenty years later his published works earned him a D.Sc. as well, from the University of London.

The academic, national, and international honours he earned were numerous. A Fellow of the Royal Society of Canada since 1958, he was also elected Fellow of the Royal Historical Society in England. He received honorary doctorates from a number of universities, and travelled widely to give invited lectures at universities in North America, Europe, Asia, Australia, and Latin America. He refused an invitation to lecture in South Africa.

Macpherson taught in the Department of Political Economy (mainly in political theory) at the University of Toronto from 1935, almost without interruptions, until his retirement in 1977, and he continued teaching a graduate seminar for several more years, attracting students from near and far.

One must mention at least one additional major service to the University of Toronto. In 1966-67 Macpherson chaired the President's Advisory Committee on Undergraduate Education. In this role he exerted a crucial influence toward accommodating student demands for curricular change, although he did not wish to reduce the academic standards long associated with the University, and in particular with its work in arts and sciences.

The work that made Macpherson famous almost overnight was his *Political Theory of Possessive Individualism: Hobbes to Locke*, published in 1962 by the Clarendon Press, Oxford. Many of his North American colleagues and students had awaited this work with high anticipation after reading his two brilliant papers on Locke's theory published in 1951 and 1954. For myself, too, these papers were an inspiration, at a time when I had never visited Canada and when the author's name was unfamiliar to me. I decided then to read everything published by Macpherson that I could lay my hands on, and this resolve has never led me to disappointment.

In addition to this great work, Macpherson published more than sixty academic papers, some of them widely republished, and some ten books, the first being *Democracy in Alberta: The Theory and Practice of a Quasi-Party*

System (1953). Other works included *The Real World of Democracy* (1965, originally a series of CBC Massey Lectures), *Democratic Theory: Essays in Retrieval* (1973), *The Life and Times of Liberal Democracy* (1977), and *The Rise and Fall of Economic Justice* (1985). He also edited several books: an edition of Hobbes's *Leviathan* (1968), one of Locke's *Second Treatise of Government* (1980), and one on a topic close to his heart, *Property: Mainstream and Critical Positions* (1978), which included two particularly incisive essays of his own.

Was Macpherson a liberal or a Marxist? People kept asking him, although the evidence seems clear enough in his writings: he was both and he was neither. A Leninist he certainly was not. He was a soft-spoken, clear-thinking democratic humanist/socialist who appropriated much of Marx's critique of the capitalist system, for the purpose of trying to rescue the theory of liberal democracy from moral and empirical blindness. His deepest concern was for equal protection for all humans in a fast-changing and increasingly dangerous world. He sought, in other words, a world without victims, and without exploited classes.

Does this vision require the prospect of a socialist regime, or even a communist world order? Brough was at his best in his lucid and learned challenge to the well-entrenched belief that the modern world must choose between, on the one hand, heavily bureaucratic systems of socialist planning aimed at equality and social welfare, and, on the other, civil liberties along with the mixed blessings of a liberal-corporate capitalism, with its commitment to "freedom" almost without limits for individual and corporate possessive individualists. He combined careful reasoning and depth of historical knowledge with a radical purpose: to try to save liberal democratic theory and practice from the blindness of its liberal adherents and supporters. He would settle for nothing less than a combination of socialism's demand for human welfare by right, and liberalism's freedom of choice.

He had faith in human nature: "We can see now that men are not by nature infinitely desirous creatures, but were only made so by the market society, which compelled men to seek even greater power in order to maintain even a modest level of satisfaction." He said this in the last of his Massey Lectures, which he concluded as follows: "Tell your politicians that the free way of life depends, to an extent they have not yet dreamed of, on the Western nations remedying the inequality of human rights as between ourselves and the poor nations. Nothing less than massive aid, which will enable the poor nations to lift themselves to recognizable human equality, will now conserve the moral stature and the power of the liberal democracies."

In 1975 Macpherson was appointed University Professor, as a token of his university's gratitude for outstanding service to it and to the world of scholarship over many years. The following year, when he was appointed an Officer of the Order of Canada, it was the Canadian Government's turn to

express the nation's gratitude. He served as president of the Canadian Political Science Association, as a member of the executive council of the International Political Science Association, as President of the Canadian Association of University Teachers, and as Chair of the (North American) Conference for the Study of Political Thought.

Brough is survived by his wife, his sister, two daughters, a son, and a grandson, also by many friends and former students, and by innumerable people in many countries who have benefited from his writings and teachings.



C. BEECHER WELD, F.R.S.C.

Donald Mainland
1902–1985





DONALD MAINLAND, born in England in 1902, obtained his M.B. CH.B. in 1925 and his D.Sc. in 1931 from the University of Edinburgh. He was a Demonstrator in Anatomy in Edinburgh until 1927 when he came to Canada as Assistant Professor of Anatomy at the University of Manitoba, where he stayed until 1930 when he became Professor and Head of the Department of Anatomy at Dalhousie University. Then he went to New York University's School of Medicine in 1950 to become Professor of Medical Statistics and was Head of the Unit until his retirement in 1970. He, and his wife, Ruth, lived in Spain for a few years before returning to the United States where he died in 1985.

In Manitoba, his publications dealt chiefly with embryology, the early development of the reproductive system of the ferret, and techniques and tests of accuracy in biological research. At Dalhousie, assisted by his students, his research and publications were on human material, including differential blood counts, muscle strength, comparison of radiography and physical examination methods in the accuracy of measurements, and problems of chance in clinical work.

His students remember him with affection and as a wonderful teacher. He cared for each of them personally and stood ready to help any of them in trouble. Occasionally students, in their dissections, would make findings that differed from the textbook, and they remember his telling them to believe their findings, not the book. He explained how some aberrations or variations were bound to occur, but insisted that they check their findings to make sure they were right. He made them think as well as memorize. He also stressed the need for research so successfully that in prewar years seven of his students were listed as co-authors in his publications. During the war, with an increased teaching schedule, this kind of collaboration became impracticable and Mainland's publications changed in character. He wrote on the treatment of laboratory and clinical data, anatomy in medical education, anatomy in a changing medical world, a textbook entitled *Anatomy as a Basis for Medical and Dental Practice*, a major paper entitled "Statistical Methods in Medical Research," and was working on a book, *Elementary Medical Statistics*, which has now gone through three editions.

At N.Y.U. he published on statistical subjects, not vital statistics, but experimental statistics as a tool to assist the biological and medical researcher in his thinking. Examples of his papers are "The Use and Misuse of Statistics in Medical Publications," "The Significance of Nonsignificance," "Safety in Numbers," and "The Planning and Evaluation of Research." He also wrote many papers on the actual application of his methods to specific clinical problems such as the evaluation of skeletal age, both in infants and the aged, arthritic diseases and the assessment of drug efficacy, and hayfever therapy in children; and he prepared tables for use in four-fold contingency tests. During his time at N.Y.U. he regularly attended ward rounds, discussing the need for statistical thinking, helping his colleagues in the use of these methods and stressing their value in the very early planning stages of research.

Donald Mainland and his wife were friendly people, interested in many things and active in art circles, but his professional work was his life. He got on very well with his colleagues and was a good committee man, but he did his own thinking and his writing was his own. His output of esoteric and practical books and fine papers was prolific and was, and remain today, remarkably useful to the medical researcher.

T.G.M. VAN DE VEN

Stanley George Mason
1914–1987



A PROMINENT Colloid and Interface Scientist, Dr. Stanley G. Mason died on 21 April, 1987, in hospital in Grand'Mere, Quebec.

For thirty-three years, until his retirement, Dr. Mason was Director of the Applied Chemistry Division of the Pulp and Paper Research Institute of Canada, as well as Professor in the Department of Chemistry at McGill University.

Dr. Mason, born in Montreal 1914, earned a chemical engineering degree at McGill University in 1936 and subsequently a doctorate in physical chemistry in 1939. After service in the Department of National Defence and in the Atomic Energy Division of the National Research Council, he began his teaching career at McGill in 1946. From 1979 to 1985 he was Otto Maass Professor of Chemistry. In 1985 McGill University named him Professor Emeritus.

His research brought him many honours, the latest being the Prix Marie-Victorin, the highest scientific distinction in the Province of Quebec. In addition he was elected a Fellow of the Royal Society of Canada, the Chemical Institute of Canada, the Technical Association of the Pulp and Paper Industry (U.S.), and the Franklin Institute. He was appointed a Foreign Associate of the U.S. National Academy of Engineering and named a Distinguished Member by the International Society of Biorheology. The American Chemical Society gave him its Anselme Payen and Kendall Awards. The Society of Rheology, (U.S.) awarded him the Bingham Medal, and the Franklin Institute awarded him the Howard N. Potts Medal. The Chemical Institute of Canada recognized his work with the presentation of the CIC Medal and the Dunlop Award.

He wrote and published over 270 scientific publications. He supervised over sixty PH.D. students in physical chemistry. Most of his papers were concerned with fundamental aspects of microrheology. The results were widely applied, not only in the pulp and paper industry but also in such diverse fields as medicine, meteorology, and environmental science.

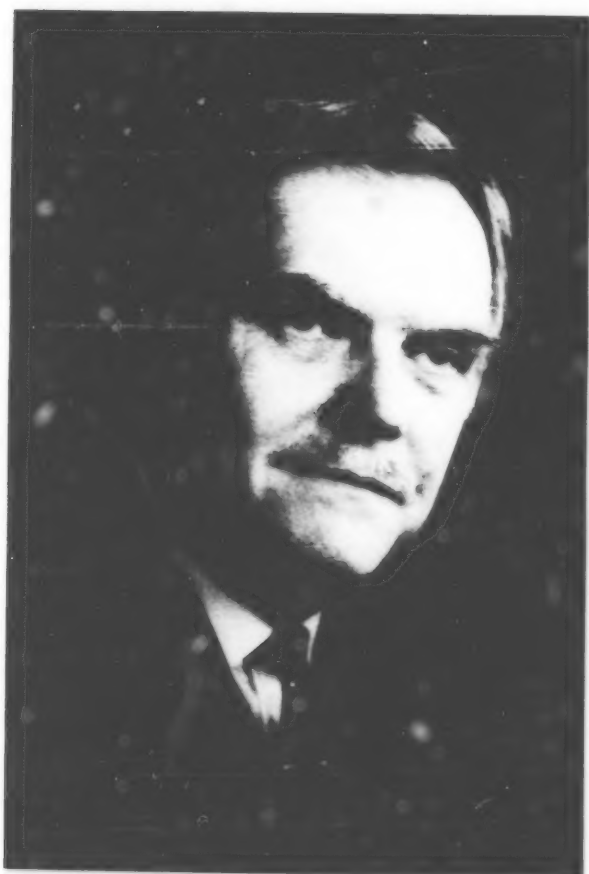
Dr. Mason, who retired in 1979, remained actively involved in science until his sudden death. The importance and excellence of his work was recognized by the *Journal of Colloid and Interface Science* in a special volume dedicated to him (Vol. 71(1), August 1979) on the occasion of his retirement.

Dr. Mason is survived by his wife, Renata, and two daughters, Cheryl and Andrea.



GORDON A.H. WALKER, F.R.S.C.

Michael William Ovenden
1926–1987





MICHAEL WILLIAM OVENDEN, Emeritus Professor of Astronomy at the University of British Columbia, died at home in Vancouver on 15 March, 1987, at the age of sixty. After suffering a heart attack in 1982, he was forced to take early retirement in late 1984, a retirement which was, sadly, all too brief. He had become an important part of the academic life not only at the University but also in the community at large. His death came as a great loss to a very large circle of colleagues and acquaintances in Vancouver.

Born on 21 May, 1926, in London, England, Michael Ovenden earned his B.Sc. (Hons.) at Queen Mary College, University of London, in 1947, after which he took a position as Junior Assistant Observer at the Observatories, Cambridge. In 1953 he joined the Astronomy Department of Glasgow University as Lecturer and, eventually, Senior Lecturer, a position he held until 1966 when he was appointed Professor of Astronomy at the University of British Columbia in the then Department of Geophysics.

He first came to Canada on a leave of absence from Glasgow to work at the Dominion Astrophysical Observatory in Victoria in 1961, a visit which must have influenced his decision to come to U.B.C. In the last twenty years, through his initial guidance, optical astronomy at U.B.C. expanded first with the establishment of the Institute of Astronomy and Space Science, and ultimately to a complement of eight faculty in the renamed Geophysics and Astronomy Department.

Michael Ovenden was one of the new generation of astronomers that emerged in Britain after World War II. Their vision and energy strongly influenced the development of astronomical facilities and research there in the 1950s and 1960s. He was a member of the British Interplanetary Society before space science became fashionable, and he was both Secretary (1946-51) and Vice-President (1951-53) of the British Astronomical Society. Later he assumed the very important position of Secretary to the Royal Astronomical Society, which he held from 1955 to 1961, becoming Vice-President in 1966. He sat on the Board of Management of the Isaac Newton Observatory (1959-63) and was a member of the Board of Visitors, Royal Greenwich Observatory in 1965. Perhaps his most important contribution in this period was as Editor of the three British professional astronomical journals, *The Observatory* (1951-53), *Monthly Notices of the Royal Astronomical Society* (1957-66), and *Quarterly Journal of the Royal Astronomical Society* (1960-66).

Throughout his career Michael Ovenden was an outstanding communicator of science and ideas. In Britain he made regular contributions to the popular *Science Progress* as well as giving radio talks, some of which were published in the *Listener*. But, more than just the facts and methods of science, he was concerned about its philosophical implications and its interaction with religion, archaeology, and the history of ideas. He considered such divisions as largely artificial. In this respect he frequently acknowledged the important influence of Sir Arthur Eddington during his formative years. In Canada, responsible scientific reporting was just getting under way when he arrived, and he played a

very significant role in its development. He produced films for schools and a series of radio programs. He was a member of the CBC Advisory Committee, Sciences and Technology, English Services Division from 1979. He had a long and fruitful association with the H.R. MacMillan Planetarium from its beginning, and co-produced several of its programs. He served as a trustee (1966-70) and Vice-President from 1979 of the Vancouver Museums and Planetarium Association, and as a member (1972-74) of the Planetarium Advisory Committee and chairman for two years (from 1980). In addition to his regular science teaching, he taught frequently in the Arts I program at U.B.C., gave a course on "The History of Ideas" at the Emily Carr College of Art, and regularly lectured under the auspices of the Knowledge Network and Continuing Education.

First and foremost Michael Ovenden was a scientist with an abiding interest in Cosmogony and Cosmology although, in recent years, he was perhaps best known for his proposed principle of least interaction action to explain the 200-year old, empirical Titus-Bode's equation, which accurately predicts most of the planetary semi-major axes. He successfully applied this principle to the satellite orbits of the major planets. His investigations in the 1970s of the apparent alignments of megaliths and medicine wheels generated much discussion. Together with John Byl he made extensive statistical investigations of stellar motions and models of galactic structure and rotation, an area now crucial to the current debate on "missing" matter. He and Archie Roy of the Astronomy Department, Glasgow, had a long standing collaboration studying pattern recognition based upon their models of the brain. Alas, he was not to see the final publication of the two papers which resulted from their work.

Michael Ovenden always maintained a lively interest in the research of others and could be relied on to make pertinent comments and constructive suggestions at seminars. I well remember a meeting of the Royal Astronomical Society in 1959 when he shrewdly anticipated the VLBI technique by asking if phase stability could be adequately maintained between unconnected aerials on, say, different continents, to allow the extension of aperture synthesis techniques to baselines larger than those then possible with connected or line of sight aerials.

Michael is survived by his wife, Irene. He leaves behind a warm memory of close friendship and lively intelligence for the large number of people who were privileged to know him.

ROSE M. JOHNSTONE, F.R.S.C.

Judah Hirsch Quastel
1899–1987



JUDAH HIRSCH QUASTEL, who was born in Sheffield, England, in 1899 and died in Vancouver in October 1987, lived through and contributed in a major way to this century's revolution in biology, a revolution that changed this discipline no less significantly than the change brought by Rutherford to physics. Quastel's basic work provided a new focus on the fundamental biological catalyst, the enzyme.

The evolution of the training of "Q" (as he was known) provides a paradigm of society's lack of attention to the financially insecure but talented young who, without higher education, would fail to reach their true potential. He was an able student who discovered the pleasures of reading at the grade school level, and remained an avid reader for a life of over eight decades. Because he was a bright boy, his father encouraged him to write qualifying exams for the British Civil Service. The family finances (and presumably the absence of any precedent) precluded any thought of his going to university. That year, however, the Civil Service exams were cancelled and so, in his father's eyes, he lost an opportunity for the "good life." His father did not object to his pursuing university training (an idea implanted in "Q's" mind by a chance encounter with an older friend), provided a scholarship could be found. "Q" won a scholarship for admission to Imperial College, London, and entered into a new world, a world of the joys of chemistry. Long before he entered university, he had fallen victim to the "magic" of chemistry, the original inspiration having been provided by an itinerant chemistry teacher in grade school.

Before he could finish his university degree, World War I broke out and he was inducted to the army. Instead of carrying a gun, he became an assistant to a pathologist who influenced his thinking and understanding of science, as well as seeding the idea of pursuing advanced studies in Cambridge.

After demobilization and completion of his undergraduate degree, "Q" made the decision to continue his studies at Cambridge. This daring adventure, made practicable by a scholarship to Trinity College and an ex-serviceman's grant, provides a striking example of the importance to society of financial support for able, but impecunious students. Such aid enabled "Q" to launch into a productive career of sixty years in biochemistry. To his own surprise he found it remarkably easy to approach Sir Frederick Gowland Hopkins for a position in his Cambridge laboratory as a graduate student and a PH.D. candidate. The memory of his pleasure at having the opportunity to work with Hopkins, and of Hopkins's personal kindness remained with him throughout his life.

The first scientific problem he tackled, despite its inauspicious beginning, has become part of the folklore of biochemistry, and of the basic understanding of dicarboxylic and tricarboxylic acid metabolism. The work began with an examination of the different ways microorganisms handle cis and trans acids, including fumaric and maleic acids. It eventually led to a deeper study of the oxidation of dicarboxylic acids to pyruvate, observations which provided key clues to the elucidation of the citric acid cycle by Sir Hans Krebs. Quastel's work also led to the discovery of the first "competitive inhibitor," malonate,

and the development of the concept of "active centres" of enzymes (a term he coined) and "antimetabolites." The long-term impact of the latter can best be judged by the important developments in recent years of new drugs for chemotherapy in cancer, neurological disorders, and metabolic diseases. Perhaps it is a comment on the integration of these concepts into modern thinking that few students in biology and biochemistry today know that malonate inhibition of succinate dehydrogenase is the origin of modern chemotherapy.

He was elected a Fellow of Trinity College in his mid-twenties, an honour he cherished throughout his life. About twenty years later, he was elected to the Royal Society of London, one of the youngest Fellows to be so honoured.

Despite his evident success in Cambridge and the charting of new paths in the study of the fundamental properties of enzymes, he realized that his career would have to be advanced outside the "Groves of Cambridge." About 1930, he took a position as biochemist at the Cardiff City Mental Hospital and obtained a grant from the Medical Research Council to work on the brain. His love of neurochemistry and brain metabolism lasted throughout his life. His investigations in Cardiff led to the discovery that barbiturates were powerful inhibitors of cerebral glucose metabolism and that glucose was the primary brain fuel. It also led to prevention of barbiturate toxicity in man by administration of large quantities of glucose.

The demonstration of acetylcholine synthesis in brain tissue *in vitro*, β -oxidation of fatty acids and the diagnosis of phenylpyruvate in the urine as an inborn error of metabolism, all arose from work in Cardiff. The work on urinary phenylpyruvate was done with Lionel Penrose and included renaming the condition phenylketonuria (PKU).

During the Second World War, as a co-opted scientist at Rothamstead Experimental Station, his work led to the discovery that 2,4-dichlorophenoxyacetic acid (2,4 D), a selective killer of dicotyledenous plants, could be used as a selective herbicide. The idea grew out of his intuition that chlorinated phenoxyacetic acids would be resistant to bacterial attack in the soil, but would share some of the toxicity of unhalogenated phenoxyacetic acids on plant roots—yet another example of putting metabolic analogues to work.

Having left Cardiff during the war, "Q" was anxious to seek greener research pastures in the post-war period. Unexpectedly, he received an offer from a former Cambridge colleague, D.L. Thomson, who was then Professor of Biochemistry at McGill University. "Q" arrived in Montreal in 1947 and lived there for some twenty years. He founded the McGill Montreal General Hospital Research Institute, a combined University and Hospital venture. All research costs were borne by external grants and much of "Q"'s time became devoted to a chase of the elusive research dollar. The Institute was filled with students from Canada and abroad. A core of about fifteen PH.D. candidates was not uncommon over the course of the next nineteen years. In addition, Post-doctoral Fellows and visiting professors from around the world made the Institute

a minor league of nations. Over seventy students took their PH.D. degrees at the Institute.

At age 65, "Q" was required to step down as Director of the McGill Montreal General Hospital Research Institute on the eve of its moving into new facilities. Retirement was anathema to him and he welcomed an invitation in 1967 to become the first Professor of Neurochemistry at the University of British Columbia, to continue research in neuroscience at the Kinsmen Laboratories in Vancouver. He spent twenty years at U.B.C. where he enjoyed his beautiful surroundings, as well as the absence of ragweed. The research into brain metabolism begun in Cardiff continued to be his major activity for nearly twenty years at the Kinsmen Laboratories.

Dr. Quastel received many honours and awards including the Meldola Medal of the Royal Institute of Chemistry (1927), the coveted Medal of l'Institute Pasteur in Paris (1954), and the Harden Medal of the Biochemical Society (U.K.) (1974). He was elected a Fellow of the Royal Society of Canada (1952) and awarded its Flavelle Medal (1974). He was named a Companion of the Order of Canada in 1970 and elected an Honorary Fellow of the Royal Society of Edinburgh in 1983. He toured India in 1965-66 as the Royal Society (London) Leverhulme Visiting Professor. He was awarded Honorary Degrees from McGill University (1969) and from the Hebrew University (1970). He was an active member of the Board of Governors of the Hebrew University for over thirty years and throughout his life a committed member of Jewish community in general.

His wife of forty-two years, Henrietta, died in 1973, and in 1975 he married Susan Ricardo, whom he predeceased. He is survived by two sons, both scientists, Michael (Ben Gurion University, Israel), David (U.B.C.), a daughter Barbara, and several grandchildren.

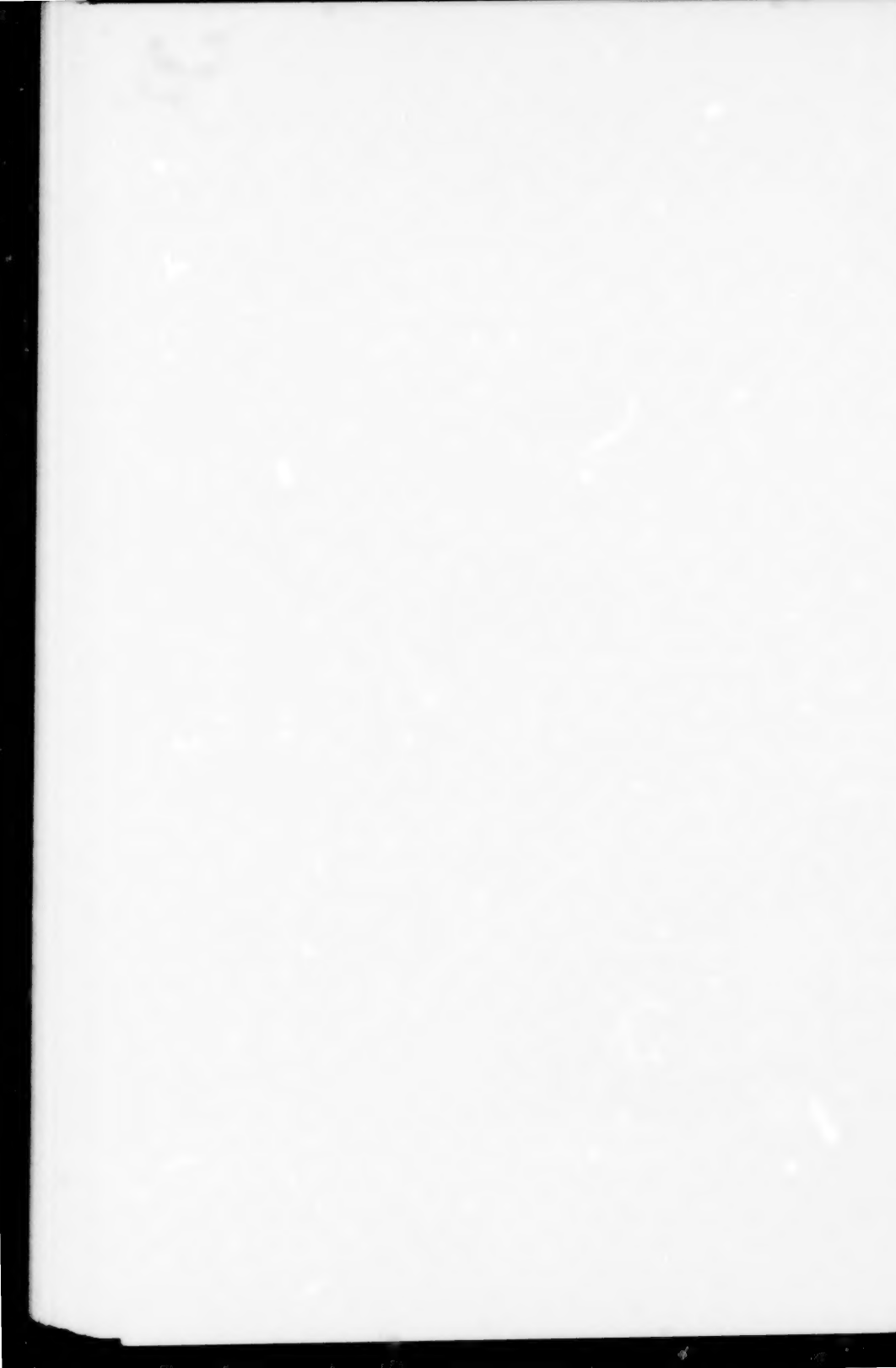
There is no doubt he loved science. His instincts and intuition served him well. He was a man of vision who could shrewdly see the significance of new observations and their potential application to human problems.

COLIN W. STEARN, F.R.S.C.

John Sinclair Stevenson
1908–1987



TRANSACTIONS OF THE ROYAL SOCIETY OF CANADA / SERIES V / VOLUME III / 1988



JOHN STEVENSON, former Dawson Professor of Geology at McGill University, died in Montreal after a short illness on 6 September, 1987. During a lifetime of service to the University and the British Columbia Department of Mines, he made important contributions to our knowledge of the mineral deposits of the Cordillera, the geology of Sudbury nickel ores, medical mineralogy and the minerals of Monteregeian intrusives, and to the training of Canadian geologists.

He was born in the farming community of New Westminster, British Columbia. His father was an immigrant from the Orkney Islands but his mother was born in British Columbia. Although he enrolled for the engineering program at the University of British Columbia, he obtained both B.A. and B.A.Sc. degrees (1929, 1930). For the former he majored in Latin, for the latter, in geology.

In 1930 he crossed the continent to study at the Massachusetts Institute of Technology under Waldemar Lindgren, and earned his doctorate in 1934. The subject of his research was the geology of the Eustis Mine in the Eastern Townships of Quebec, not far from Montreal where he spent most of his career. In classes in mineralogy he met a Radcliffe student from Seattle, the only woman enrolled in geology. After graduation they were married and she became not only his wife, and mother of two sons, but also a collaborator in his research, and co-author of several papers.

In 1935 John and Louise Stevenson moved to northern Ontario where he supervised drilling for Long Lac Gold Mines. At the end of that season he joined the British Columbia Department of Mines in Victoria, and devoted the next fifteen years to the study of mineralization in the Coast Range. During this period he wrote comprehensive monographs on the mercury, molybdenum, tungsten, lode gold, and uranium deposits of the province. During World War II he was active in the search for strategic minerals. To extend his understanding of the origin of these deposits, he travelled on a Guggenheim Fellowship for nine months during the winter of 1947-48 to twenty-one universities and institutions in the United States consulting with research workers in mineral deposits.

In 1950 he was hired as Associate Professor at McGill University to teach mineralogy, on the retirement of R.P.D. Graham. He taught courses at several levels in mineralogy, but was best known for his teaching in ore mineralogy. He was promoted to a full professorship in 1961 and to the Dawson chair in 1971. During the mid-sixties he served as chairman of the Department of Geological Sciences. Although he officially retired in 1974, he continued to teach courses for the next ten years in special capacities. During his teaching career he supervised research for twenty-one doctoral and twenty master's theses at McGill. His contributions to the graduate program in Mineral Exploration were recognized in 1978 when his former students established the Stevenson Medal to be given each year to the outstanding student in that program.

At McGill he concentrated his research over a period of thirty years on the

Sudbury basin, as consultant for the International Nickel Company. During the 1950s and 1960s he led field parties mapping the surface geology. His work was particularly concerned with the petrology of the Sudbury basin intrusive rocks and the Onaping tuff, which he believed was of pyroclastic origin. He also consulted on the geology of other mines and prospects for the company in the Manitoba nickel belt. He was an advocate of the magmatic origin of Sudbury ores when the hypothesis of meteorite impact was becoming popular. His last paper on this subject which will be published posthumously, was presented in the summer of 1987 in South Africa to the International Workshop on Cryptoexplosions and Catastrophes in the Geological Record.

John Stevenson made contributions to mineralogical problems, such as the occurrence of native arsenic and dawsonite, in the Monteregian intrusives of Quebec. With his wife he studied the mineralogy of kidneystones and of the teeth of fossil reptiles.

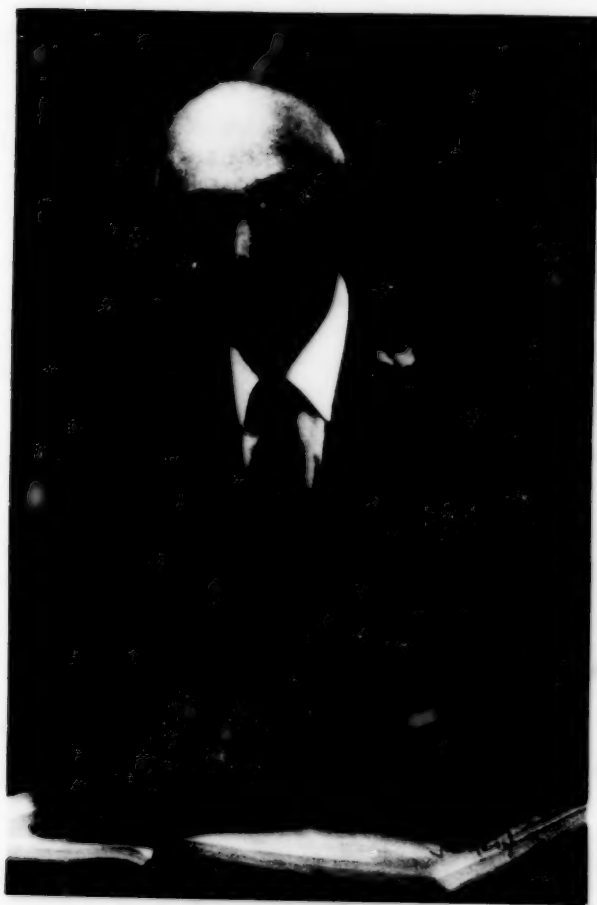
He was a founding member of the Mineralogical Association of Canada and served three terms as its president. He was also an active member of the Canadian Institute of Mining and Metallurgy, the Mineralogical Societies of America and Great Britain, the Geochemical Society, the Society of Economic Geologists, and the National Association of Geology Teachers. He was president of the local chapter of Sigma Xi in 1966-67.

Elected to Fellowship in the Royal Society in 1949, he served as chairman of the program committee of Section IV (Earth Sciences) in 1960-61, and was editor of *Tectonics of the Canadian Shield*. For many years he arranged for the publication of the obituary notices of fellows of the Earth Sciences division.

John Stevenson's contributions to the geology of Canadian mineral deposits and his enthusiasm in teaching and research in mineralogy will long be remembered by his colleagues and students.

ALAN M. GOODWIN, F.R.S.C.

Clifford Howard Stockwell
1897–1987



TRANSACTIONS OF THE ROYAL SOCIETY OF CANADA / SERIES V / VOLUME III / 1988



CLIFFORD HOWARD STOCKWELL, distinguished scientist of the Geological Survey of Canada and a Fellow of the Royal Society of Canada for more than half a century, died on 26 April, 1987, in Ottawa in his ninetieth year.

Cliff, as he was affectionately known to his many friends, was born in Estevan, Saskatchewan, on 26 September, 1897. He showed an early interest in natural sciences and outdoor activities, a combination that led him to pursue a career in geology. Following a three-year stint with the R.C.A.F. (1917–1919) he graduated with the B.Sc. degree at the University of British Columbia in 1924, followed by the Ph.D. degree at the University of Wisconsin in 1930. In 1922 he had worked for the Geological Survey of Canada on a summer field party in Western Canada. This experience crystallized his ambition and, in 1927, he first joined the Geological Survey of Canada on a six-month trial, at the princely rate of \$2220 per year! He spent the following fifty-five years with the Survey, Canada's premier geological organization, including leaves of absence in 1947–48 as Professor at McGill University, and in 1951–52 as consultant with New Jersey Zinc Company. Formal retirement in 1967 at age seventy was followed by a particularly productive fifteen year period on annual contracts, culminating in 1982 with one of the most highly respected publications.

Cliff Stockwell's professional career personifies Canadian geology at its best, combining a rich assortment of field mapping and laboratory-based studies. From 1922 to 1955 he was engaged in almost continuous field mapping and report writing across the vast Canadian Shield, in Manitoba-Saskatchewan, the Northwest Territories, Yukon, and Quebec. During this period he established his well-recognized reputation for careful, reliable scientific work. His legendary mapping ability constitutes a lasting contribution to the understanding of Precambrian geology and the evolution of the Canadian Shield and its mineral deposits. During this period his field assistants included N.B. Keevil (1930), J.W. Ambrose (1934), C.S. Lord (1936), J.M. Harrison (1938), H.B.D. Wilson (1939), Y.O. Fortier (1940), N.R. Gadd (1943), and J.O. Kalliokoski (1947)—all destined to become leaders in Canadian geology and all beneficiaries of this man's remarkable geological talents.

In 1956 Cliff Stockwell became chief of the Precambrian Division of the Geological Survey of Canada. During the next three years, in addition to administering this large, diverse division, he edited the fourth edition of *Geology and Economic Minerals of Canada*, an important and highly regarded synthesis.

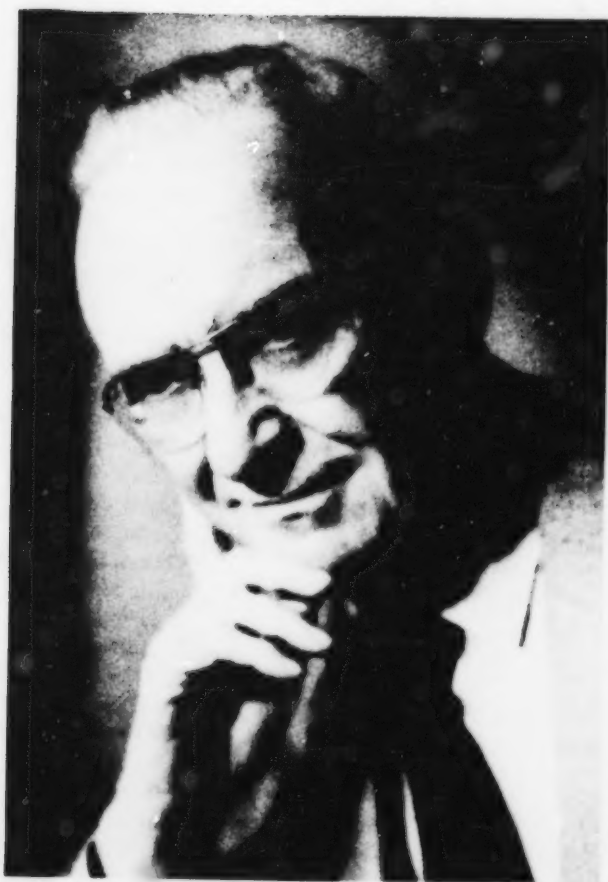
In 1958 he side-stepped from this heavy administrative position to Special Projects. In this select position he began perhaps his most productive phase, namely the preparation of a Tectonic Map of Canada, based on all published and unpublished data modified by isotope studies. This last aspect reflected the growing appreciation of isotopic and geochronologic studies as a method of establishing the absolute time frame of geological events. At this time, the Geological Survey of Canada was involved in unusually large-scale and

widespread helicopter-supported regional geological mapping projects across the breadth of Canada, including hitherto difficult-to-reach far northern parts. The resulting surge in data and rock samples provided a unique opportunity for investigating time-rock classification systems applicable to the Canadian Shield. This led in 1961 to publication of a seminal report, *Structural Provinces, Orogenies, and Time-Classification of Rocks of the Canadian Precambrian Shield*. This single publication has probably given more stimulation to modern scientific study of the subject than any other. It provides a basic tectonic classification based on defined orogenies of the Canadian Shield whose terminations define boundaries between the major time units and their subdivisions. Recognizing the uncertainties involved in the nature and interpretation of geochronologic data, he had the wisdom to define the orogenies by type localities and not isotopic age, which varies with the method used and involves a margin of error. He thus focused on the rocks as the standard in defining the orogenies, regardless of future revisions of their isotopic ages. On this basis, the Canadian Shield was divided into recognizable tectonic provinces, a division that prevails to this day as a memorial to his prescience and understanding of Precambrian geology.

Cliff Stockwell was a Member of the Canadian Institute of Mining and Metallurgy, a Member of the Geological Association of Canada, a Fellow of the Royal Society of Canada, and Fellow of the Geological Society of America. He was awarded the Barlow Memorial Medal of the CIMM in 1944, and the Willet G. Miller Medal of the Royal Society of Canada in 1953. He will be long remembered by a host of friends and admirers for his outstanding contributions to the geology of Canada and to Precambrian studies of the world.

RUTH E. GRAHAME, M.D., M.SC.

Ian Maclaren Thompson
1896-1981





IAN MACLAREN THOMPSON was born in Newfoundland in 1896. From 1914 to 1920 he was a student at the University of Edinburgh, obtaining a medical degree in 1920. During 1917-18 he was surgeon-probationer in the R.N.V.R., and was wounded at the sinking of H.M.S. *Strongbow*. He was mentioned in dispatches for his service in the first defence of a British convoy.

Following his studies at Edinburgh, he became lecturer and then assistant professor of Anatomy at McGill University, 1920-27. He joined the faculty of the University of California at Berkeley, becoming Chairman of the Division of Anatomy in 1930, but in 1937 he returned to Canada as Professor and Head of the Department of Anatomy at the University of Manitoba, where he remained until his retirement in 1965.

Dr. Thompson was author of more than eighty publications, including several books. His research was primarily in the field of neuroscience, but his monograph on variations of the bile ducts and hepatic and cystic arteries is still quoted. He lectured frequently on a variety of subjects, including medical history, the teaching of anatomy and the philosophy of science and medicine.

His researches gained him election as a Fellow of the Royal Society of Canada (1947) and as a Fellow of the Royal Society of Edinburgh (1952). The University of Manitoba conferred upon him an honorary degree (D.Sc.) in 1972, and he was the recipient of the J.C.B. Grant Award of the Canadian Association of Anatomists in 1980.

His other distinctions included the following: President of the Canadian Association of Anatomists, the Manitoba Medico-Legal Society, and the Manitoba Museum Association; Chairman of the Board of the Canadian Federation of Biological Societies; member of the Council of the American Association of Anatomists, and of the Council of the Anatomical Society of Great Britain and Ireland; Honorary President of the Manitoba Medical Students' Association (1942-43), Life Member of the Winnipeg Medical Society, the Manitoba Museum of Man and Nature, and the Scientific Club of Winnipeg; honorary member of the Omicron Kappa Upsilon (dental honour society); and Honorary Secretary of the Winnipeg Clinic Research Institute. The high regard that the University of Manitoba anatomy staff had for him was symbolized by the naming of the Department of Anatomy Library as the I. Maclaren Thompson Reference Library.

He organized the teaching of anatomy at the University of Manitoba, abolishing separate courses and developing a single comprehensive course, which included gross anatomy, histology, neuroanatomy, embryology, radiographic anatomy, and normal "living" anatomy. All these aspects of anatomy were taught as simultaneously as was feasible. In addition he set up anatomical clinics that took undergraduate medical students into the hospital to study sick and injured patients from an anatomical viewpoint.

Dr. Thompson played a major role in the formation of the Manitoba Anatomy Act of 1947, which has served as a model.

His use of the English language was always a source of pleasure to students

and colleagues. He used words precisely and with grace and wit. His lectures were lucid, interesting and eagerly attended by students. Into his lectures he wove anecdotes illustrating the anatomical basis of medicine. Poetry was often included in the lectures and his use of quotations from the operettas of Gilbert and Sullivan, delighted everyone.

Dr. Thompson enjoyed the respect and affection not only of his colleagues, but of the hundreds of students who passed through the Department of Anatomy. He was a man of civility, grace, wide knowledge and broad interests.

At his death in 1981 he was survived by his wife Christian, who died in 1986.

JAMES HAMILTON TULLY

John Patrick Tully
1906–1987



TRANSACTIONS OF THE ROYAL SOCIETY OF CANADA / SERIES V / VOLUME III / 1988

DURING THE COURSE of his long and distinguished career, and with the tireless application of his formidable intellect and dynamic personality, John Patrick Tully played a leading role in laying the foundations of, and bringing international recognition to, the oceanographic sciences in Canada. As he often said, he was one of the pioneers, and it is not too much to say that, on 19 May, 1987, we lost one of the most widely respected pioneering spirits of the formative years for Canadian marine science.

Born in Brandon, Manitoba, in 1906, John Tully received his B.Sc. from the University of Manitoba in 1931. In the same year he took up the position of Assistant Scientist at the Marine Biological Station, Fisheries Research Board of Canada, in Nanaimo, British Columbia. It was there on Vancouver Island that he made his career as part of that remarkable group of scientists who developed Canadian oceanography. From 1942 to 1946 he was seconded to the Royal Canadian Navy. He returned to Nanaimo in 1946 as Oceanographer in Charge of the Pacific Oceanographic Group and remained there until 1966. During this period he received his Ph.D. from the University of Washington (1947) and also taught part-time at the University of British Columbia (1949–1959). In 1966 he moved to Ottawa for four years as the Senior Consultant to the Chairman of the Fisheries Research Board and as the Secretary of the Canadian Committee on Oceanography. He retired to Nanaimo in 1969 and continued his work through occasional consulting until 1975.

Initially his research was on oyster quality and nutrition, and on sea water analysis. After 1936 he turned more to coastal and physical oceanography. His works on estuarine circulation and flushing, as well as on the structure and circulation of the Northwest Pacific Ocean, are considered classics by students and professional oceanographers worldwide. During World War II he worked on Airborne Radiation Thermometry, underwater acoustics, and SONAR. His research spanned a wide range of fields: theories of the circulation of oceans and coastal waters, pollution research on pulp mill and urban sewage effluents, hydraulic modelling, tidal movements, salmon migration, and long-term temperature and salinity changes. There are over one hundred publications.

His research always had a practical orientation, about which John Tully, as his friends know well, was quite emphatic. This can be seen, for example, in the large number of marine surveys of various types that he was involved with from 1931 onward. Moreover, his practical bent was informed by three overriding concerns. The first was that oceanography should help us to understand the oceans as rich and complex life-cultures with their own integrity, so that when humans use the oceans—as they must—they will do so with understanding and respect. In this respect he was specifically concerned with the Pacific salmon fisheries.

The second concern was with pollution, especially municipal sewage and pulp mill effluents. He tried to walk a thin line between those who wanted no restriction on marine pollution and those who wished to stop industrial and municipal use of the seas altogether. A great deal of his work was designed to

throw scientific light on the vital issue of how much and with what kinds of human waste the life-cultures of the coastal waters can cope without damage. Because he felt so strongly that science should speak to important issues such as this, he did not hesitate to make his recommendations public. As a result, he was often misunderstood and criticized.

His third concern was that the various sciences involved with the oceans should work together and combine their resources to solve the practical problems of the use of the oceans in an ecologically sensitive and benign manner. Just before he died he told me that he hoped he had played a part in establishing a tradition of research in which oceanographers, marine biologists, hydrographers, and meteorologists could work with fishermen, industrialists, governments, concerned citizens, and environmentalists to solve our common problems. How successful he has been will be decided by those women and men who have worked with him and been touched by his vision and love of the ocean.

These three concerns were not restricted to the West Coast or even to Canada. In Tokyo, Paris, Moscow, Washington, and the UN, he tried (unsuccessfully) to persuade governments to work together in a co-operative and pragmatic manner on global marine problems. He aided in establishing many joint programs in oceanography with Japan, the USSR and the United States. He served on the Intergovernmental Oceanographic Commission and the World Meteorological Organization in the development of joint ocean and meteorological services. Furthermore, he was the first chairperson of the Integrated Global Ocean Stations System and a member of many Canadian and international scientific organizations.

For his work during World War II he was awarded an M.B.E. and he received the Coronation Medal in 1953. He was president of the Western Division of the American Association for the Advancement of Science in 1963. In 1964 he was elected a Fellow of the Interdisciplinary Subject Division of Academy III of the Royal Society of Canada. In 1967 he received the *Medaille Commemorative de Prince Albert I de Monaco* (the Manley-Bendall Prize). The Canadian Meteorological and Oceanographic Society instituted the J.P. Tully Medal in 1984, to be given annually to a scientist whose work, influence and personal qualities have earned peer respect. The Canadian Port and Harbour Association Medal was awarded to him in 1985.

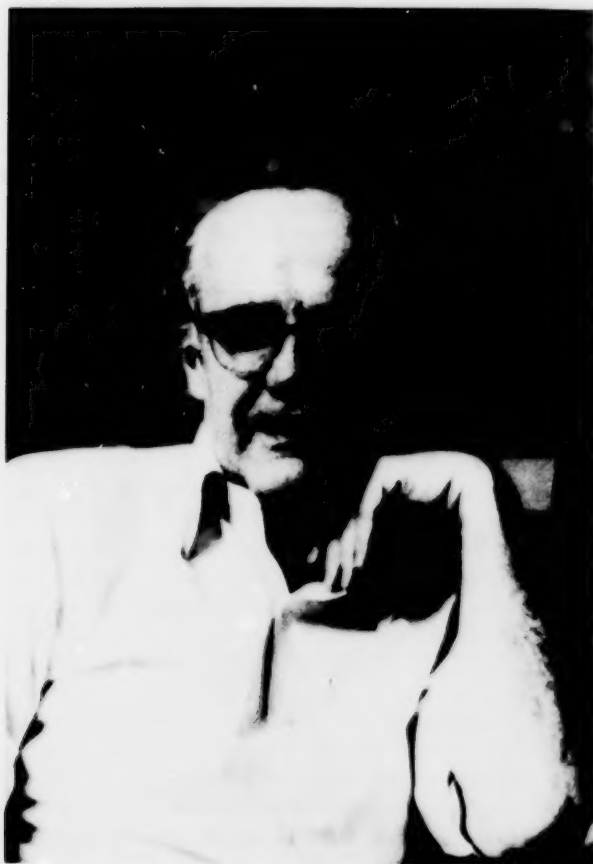
His greatest honour came in 1985 when the Canadian Department of Fisheries launched a new research vessel for work on the West Coast and in the Arctic Ocean—the *CSS John P. Tully*. He was simply overwhelmed when, confined to his wheelchair, he gazed out from his livingroom window to see this beautiful ship sail past, through his beloved Straits of Georgia, with all its promise of continuing the tradition of research that he helped to pioneer.

In late July 1987 a small service was held aboard the *CSS John P. Tully* and the ashes of John Tully were scattered on the Chukchi Sea.

ATHANASIOS ASIMAKOPOULOS, F.R.S.C.

John Cathcart Weldon

1922–1987



TRANSACTIONS OF THE ROYAL SOCIETY OF CANADA / SERIES V / VOLUME III / 1988



J.C. WELDON was an inspired teacher, whose influence went far beyond the classroom. His superb intellect and clarity of expression and thought, combined with a strong interest in economic problems, continually fascinated students. Some chose to specialize in economics after taking his courses, and those who opted for other careers continued to find valuable many of the things they learned from him. Weldon devoted considerable time to the explanation of economic issues to laymen on radio and television programs, in newspaper articles, speeches to trade union organizations, and in pamphlets on topics such as public pensions and income policies. His reputation, both as a theorist and as an expositor, was such that he was often asked to appear as a witness by Royal Commissions. He had close ties with the C.C.F. and with its successor, the N.D.P., because of his attachment to social democracy. He served, very effectively, as Secretary for Planning on the Planning and Priorities Committee of Cabinet, Government of Manitoba, 1970-72. He was also an active churchman, and served his church, St. John the Evangelist, in many capacities.

Weldon was born in Magpie Mine, Ontario, but his family moved to Montreal when he was very young. In 1939 he enrolled at McGill University to study Mathematics and Physics, but he left in 1941 to join the R.C.A.F. and, on his return in 1945, a strong interest in economic and social problems led to a switch of enrolment to Economics. He began his graduate studies in 1947, and spent the academic year 1948-49 at Columbia University before returning to McGill as a Lecturer. His Ph.D. thesis, completed in 1952 for McGill, examined the role of entrepreneurship in theories of income distribution. Weldon was elected a Fellow of the Royal Society of Canada in 1975, and served as president of the Canadian Economics Association in 1975-76.

Weldon's academic specialization was in economic theory, and he was particularly interested in the logical foundations of theoretical analyses. Social welfare functions, their significance, and how they could be conceptualized in an historical context as the corpus of the society changed, with one set of generations trying to affect the actions of succeeding generations, was an ongoing area of research. This was extended to a consideration of the economic logic of saving, which made use of insights he had obtained in his treatment of intergenerational transfers and public pensions. There were several very solid publications, but Weldon never wrote the seminal books, or the many substantial articles that his exceptional ability put within his grasp. This was the cost paid for his wide range of interests and involvement in many activities. His research effort during the last dozen years of his life was concentrated on a huge work in the history of economic thought that was combined with the teaching of a course in that field. Well over fifteen hundred pages had been distributed to students, and Weldon was in the process of editing the materials into forms suitable for publication, when his fatal illness struck during the summer of 1986.

All of Weldon's academic life was spent at McGill, and he devoted a great deal of time and energy in building a vibrant department that had a varied

outlook on the contents of, and approach to, economics. He was a natural leader among academics, with his ability to hold his own intellectually in any group, and his genuine interest in the welfare of students and colleagues. He was head of the economics section of the Department of Economics and Political Science before it split into separate departments in 1969. He was the clear choice as first chairman of the new department, a position he also held from 1972 to 1974 on his return from governmental duties in Manitoba. Weldon was an inspirational leader, and he remained the dominant personality in the department throughout his career, but the details of administrative work were sometimes left undone, and a few decisions on students and staff reflected his great compassion rather than considered judgment. The university that he graced with his presence, and to which he devoted so much time and effort in the things that should really matter in universities—great care with teaching and concern with individuals—turned out in the end to be unconcerned about the failure of its administration to observe a basic rule that Weldon considered to be one of the foundations of a democratic society. He believed that it was vital for all organizations, especially for those supported by public funds, to uphold the rule of law that should bind all, no matter what rank they hold in the administrative hierarchy. Weldon fought the university administration, at great personal cost, when it failed to observe its own rules on promotion in the department. The university administration's response to his public denunciation of its failure to abide by its own rules involved still further departures from accepted behaviour. Third-party investigations of these matters have vindicated Weldon's objections to the procedures used against him, but the university administration continues to refuse to rectify matters. (For details see the *Bulletin of the Canadian Association of University Teachers* for October 1983 and May 1987).

The warm, personal side of this gifted man should not be neglected. There was a special, impish, quality to his personality that made him a favourite with a wide range of people. Weldon's sense of humour lightened even the darkest moments, and his presence was always a source of comfort that will be greatly missed. He is survived by a son, John, a daughter, Susan, and two grandchildren.

Appendix: Publications of the Royal Society of Canada Publications de la Société royale du Canada

The Royal Society of Canada publishes:

- Minutes of its *Proceedings* at the Annual Meeting;
- an annual volume of the Society's *Transactions*;
- *Proceedings* of Symposia;
- *Diversa* (Newsletter) and
- *Calendar* of Fellows.

La Société royale du Canada publie:

- Les *Délibérations* du Congrès annuel de la Société;
- Les *Mémoires* présentées au Congrès annuel de la Société;
- Les *Comptes rendus* des colloques;
- *Diversa* (Notes et Nouvelles) et
- l'*Annuaire* des membres.

A summary statement on *The Royal Society of Canada - 1882-1982* is available without charge from the Secretariat.

On peut se procurer gratuitement au Secrétariat un exposé sommaire sur *La Société royale du Canada - 1882-1982*.

Proceedings and Transactions

The *Proceedings* and the *Transactions* appear annually in two separate volumes. Fellows receive copies of the current issues without charge. For current issues the prices to non-Fellows are \$6.75 for *Proceedings* and \$13.50 for *Transactions*. Some earlier volumes are available for purchase at prices depending on scarcity and condition. Inquiries and orders should be sent to the Royal Society of Canada.

Délibérations et Mémoires

Les *Délibérations* et les *Mémoires* paraissent chaque année en deux volumes distincts qui sont distribués gratuitement aux membres. Le grand public peut acheter les dernières livraisons des *Délibérations* à 6,75\$ l'exemplaire et les *Mémoires* à 13,50\$. Il est encore possible de commander certains volumes antérieurs, le prix dépendant

de l'état de la publication et du nombre d'exemplaires disponibles. Prière d'adresser toutes demandes de renseignements ou toutes commandes à la Société royale du Canada.

Index 1882-1982

The Index consists of author and subject entries for all papers published in the *Transactions* and other publications of the Society. Available for \$30.

L'Index auteurs-matières renvoie ainsi à toutes les communications des *Mémoires* et d'autres publications de la Société. Prix: 30,00 \$.

Studia Varia

The scope of these volumes is indicated by the titles. Most volumes are now out of print. Asterisks (*) indicate those volumes that are available through the Royal Society; all others continue to be available through the on-demand publishing program of University Microfilms, Ann Arbor, Michigan, U.S.A.

Le titre des volumes déjà parus indique la portée de ces études. La plupart de ces volumes sont épuisés. Les astérisques (*) indiquent les volumes disponibles au Secrétariat de la Société. On peut se procurer les autres volumes en s'adressant à University Microfilms, Ann Arbor, Michigan, U.S.A.

Studia Varia, E.G.D. Murray, ed., 1957, 136 pp.

Our Debt to the Future, E.G.D. Murray, ed., 1958, 142 pp.

The Canadian Northwest: Its Potentialities, Frank H. Underhill, ed., 1959, 112 pp.

Evolution: Its Science and Doctrine, T.W.M. Cameron, ed., 1960, 254 pp.

Aux sources du présent, Léon Lortie et Adrien Plouffe, eds., 1960, 122 pp.

Canadian Universities Today, George F.G. Stanley and Guy Sylvestre, eds., 1961, 108 pp.

**Canadian Population and Northern Colonization*, V.W. Bladen, ed., 1962, 168 pp., \$4.50

Higher Education in a Changing Canada, J.E. Hodgetts, ed., 1966

Pioneers of Canadian Science, G.F.G. Stanley, ed., 1966

Structures sociales du Canada français, Guy Sylvestre, éd., 1966

**Water Resources of Canada / Ressources hydrauliques*, C.E. Dolman, ed., 1967, 249 pp., \$8.50

Scholarship in Canada 1967: Achievement and Outlook, R.H. Hubbard, ed., 1967

**Visages de la civilisation au Canada Français*, L. Lamontagne, éd., 1970, \$7.50

**Le Canada français d'aujourd'hui*, L. Lamontagne, éd., 1970, \$7.50

Special Publications / Publications spéciales

Collections of specialized scientific papers on a single theme or related themes have been published for the Society from time to time. Most volumes are now out-of-print. Asterisks (*) indicate those volumes available through the Secretariat of the Society; all others continue to be available through the on-demand publishing program of University Microfilms, Ann Arbor, Michigan, U.S.A.

On a publié de temps en temps, pour le compte de la Société, des collections d'ouvrages portant sur un thème unique ou sur des questions connexes. La plupart de ces volumes sont épuisés. Les astérisques (*) indiquent les volumes disponibles au Secrétariat de la Société. Les autres volumes sont disponibles sur demande à University Microfilms, Ann Arbor, Michigan, U.S.A.

- The Grenville Problem*, James E. Thompson, ed., 1956
The Proterozoic in Canada, James E. Gill, ed., 1957
**Soils in Canada*, Robert F. Legget, ed., 1961, water damaged copies, \$5.50
Tectonics of the Canadian Shield, J.S. Stevenson, ed., 1962
**Marine Distribution*, M.J. Dunbar, ed., 1963, 110 pp. \$5.00
**Studies in Analytical Geochemistry*, Denis M. Shaw, ed., 1963, \$5.95
Crucial Maps in the Early Cartography and Place-Nomenclature of the Atlantic Coast of Canada, with an Introductory Commentary and Map Notes by Theodore E. Layng, W.F. Ganong, ed., 1964
**Geochronology in Canada*, F. Fitz Osborne, ed., 1964, \$5.95
Continental Drift, G.D. Garland, ed., 1968
**Appalachian Tectonics*, T.H. Clark, ed., 1967, 99 pp., \$6.50
**The Earth Sciences in Canada: A Centennial Appraisal and Forecast*, E.R.W. Neale, ed., 1968, 259 pp., ISBN 0 920064 05 1, \$8.50
**Glacial Till—An Interdisciplinary Study*, Robert F. Legget, ed., 1976, 412 pp., ISBN 0 920064 11 6, \$15.00
**Energy Flow—Its Biological Dimensions (The IBP in Canada 1964–1974)*, T.W.M. Cameron and L.W. Billingsley, eds., 1975, 322 pp., ISBN 0 920064 05 1, \$5.00
**Nuclear Issues in the Canadian Energy Context*, E.P. Hincks, ed., 1979, 279 pp., ISBN 0 920064 13 2, \$8.00
**Nuclear Winter and Associated Effects: A Canadian Appraisal of the Environmental Impact of Nuclear War / L'hiver nucléaire et ses effets connexes*, F.K. Hare, A. Forester, eds., 1985, 382 pp., ISBN 0 920064 21 3, \$15.00

Proceedings of Symposia / Comptes Rendus des colloques

These volumes comprise the papers presented at symposia held from time to time to deal with matters of scholarly and public importance. The contents in all cases are presented in English or French, depending on the language of the speaker. They are sold by the Secretariat of the Society unless indicated otherwise.

Ces volumes réunissent les communications présentées aux colloques tenus de temps en temps pour étudier des sujets importants dans les domaines d'intérêts public et du savoir. Elles paraissent, la plupart du temps, en anglais ou en français, selon la langue utilisée par le conférencier. On peut se les procurer au Secrétariat de la Société sauf les quelques cas indiqués.

- 1 *The Tundra Environment*, F. Kenneth Hare, ed., 1970, \$2.00
- 2 *Mercury in Man's Environment*, J.E. Watkin, ed., 1971, 201 pp., \$5.00
- 3 *Communication into the Home / Communications au foyer*, W.C. Brown, ed., 1972, \$3.00
- 4 *Futures Canada / L'avenir du Canada*, J.T. Wilson, ed., 1973, 71 pp., \$2.00
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